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INVENTORY

PARTICIPANT GUIDE FOR TQM QUANTITATIVE METHODS WORKSHOP

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May 30, 1990

DEPARTMENT OF DEFENSE

PARTICIPANT GUIDE
FOR
TOTAL QUALITY MANAGEMENT (TQM)
Quantitative Methods Workshop

Prepared For:
The Office Of
The Secretary
Of Defense

Prepared Through:
The Office Of
Personnel Management
Contract Number Opm-87-9038

Prepared By:
Booz • Allen & Hamilton Inc.
Human Resource Management Practice
4330 East West Highway
Bethesda, Maryland 20814

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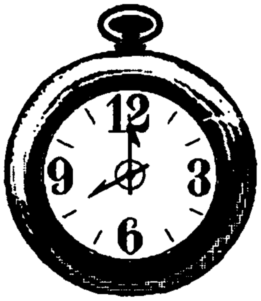

DAY ONE

08:30 - 09:00	Introductions & Course Overview
09:00 - 09:45	Module 1, TQM Awareness Review
09:45 - 10:00	Break
10:00 - 12:00	Module 2, Scientific Method and PDCA
12:00 - 01:00	Lunch
01:00 - 02:30	Module 3, Statistical Theory and Tools
02:30 - 02:45	Break
02:45 - 04:00	Module 3 (Continued)

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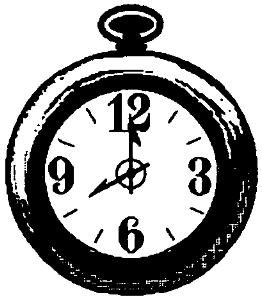

DAY TWO

08:30 - 09:00	Review Day 1
09:00 - 09:50	Module 4, Planning and Doing
09:50 - 10:00	Break
10:00 - 10:50	Module 4 (Continued)
10:50 - 11:00	Break
11:00 - 12:00	Module 4 (Continued)
12:00 - 01:00	Lunch
01:00 - 01:50	Module 5, Checking and Acting Part 1
01:50 - 02:00	Break
02:00 - 02:50	Module 5 (Continued)
02:50 - 03:00	Break
03:00 - 04:00	Module 5 (Continued)

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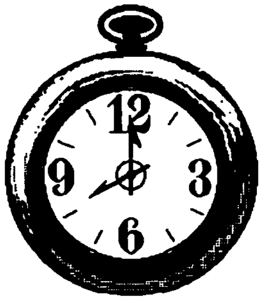


DAY THREE

08:30 - 09:00	Review Day 2
09:00 - 09:50	Module 6, Checking and Acting Part II
09:50 - 10:00	Break
10:00 - 10:50	Module 6 (Continued)
10:50 - 11:00	Break
11:00 - 12:00	Module 6 (Continued)
12:00 - 01:00	Lunch
01:00 - 01:50	Module 6 (Continued)
01:50 - 02:00	Break
02:00 - 02:50	Module 6 (Continued)
02:50 - 03:00	Break
03:00 - 03:30	Course Review
03:30 - 04:00	Course Evaluation

Course Objectives

Upon completion of this course, the participant will be able to:

- Describe the Plan, Do, Check, Act (PDCA) Cycle.
- List quantitatve methods used in each phase of the PDCA Cycle.
- Compute the mean, mode, median, and standard deviation
- Explain how the mean, mode, median, and standard deviation are applied in Total Quality Management.
- Develop flow charts and cause and effect diagrams.
- Construct check sheets, Pareto charts, histograms, scatter diagrams, run charts, and control charts.
- Apply quantitatve methods to the study of DoD processes.
- Describe the process control and improvement cycle.

MODULE ONE

TQM REVIEW

Module One Objectives

Upon completion of this module, the participant will be able to:

- Define TQM.
- Summarize the evolution to TQM.
- Describe the TQM infrastructure.
- List the elements of TQM.
- Describe the focus on process.
- Explain why quantitative methods are used in TQM.

TQM Review

- The purpose of this module is to provide participants with a brief review of major TQM concepts and principles. If you need additional information, please refer to the student manual, Total Quality Management (TQM) Awareness Seminar, that was provided for the Awareness Course. You may also refer to the Reterence section provided at the end of this manual for additional readings.

DoD TQM Definition

Total Quality Management (TQM) is both a **philosophy** and a set of **guiding principles** that represent the foundation of a **continuously improving** organization. TQM is the application of **quantitative methods** and **human resources** to improve the material and services supplied to an organization, and the degree to which the **needs of the customer** are met, now and in the future. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools under a **disciplined approach** focused on continuous improvement.

TQM Review

- This definition is further reinforced by supporting statements from the Secretary of Defense.

  Reference:

  DoD 5000.51G (Draft). Total Quality Management Guide, August 1, 1989.

- There is no universal definition of TQM. However, several TQM experts agree that some components must be present and working in order for TQM to be achieved. The key components are highlighted in bold print in the above definition.

Evolution to Total Quality Management

American Management

1st generation	**Management by DOING**
2nd generation	**Management by DIRECTING**
3rd generation	**Management by RESULTS**
4th generation	**Management by METHOD/ QUALITY MANAGEMENT**

TQM Review

- American management has built the strongest economy the world has known.
  - The ability of the United States to produce large quantities of high-quality armaments using an unskilled labor force won World War II.
  - In the 1950's, after the war ended, the lessons on quality and productivity were essentially discarded. After World War II, the United States was expanding its economy at record rates and providing relief programs to the rest of the world.

- American management styles have progressed through the years:
  - The first generation of management "did it yourself."
  - In the second generation, a master craftsman directed his apprentices.
  - The most widely used management style today in the U.S. is management by results or controls (also known as management by objectives (MBO)), which provides a systematic hierarchy of control and accountability.
  - The new and more effective management style to take us into the 21st century is management by method.
- The major difference is the *shift in emphasis* from results to establishing what needs to be done and ensuring that the *process* is optimized.

<u>Reference</u>:

Joiner, Brian L.; Scholtes, Peter R., "Total Quality Leadership vs. Management by Control." Joiner Associates Inc., Madison, WI, 1985.

Total Quality Management Infrastructure

Executive Steering Committee

- The *Executive Steering Group* and *senior management* are responsible for providing leadership.
- Creating a quality culture is a result of a long-term commitment.
- Leaders must drive out fear.
- Top-level leaders must accept the challenge.

TQM Review

The Executive Steering Group and senior management must be responsible for providing leadership to improve the system through effective communication and team building.

- Creating a quality culture is a result of a long-term commitment to TQM, and can be achieved only through leadership toward a long-range vision.
- Leaders must drive out fear to promote innovation, risk-taking, pride in workmanship, and continuous improvement.
- Top-level leaders need to accept the challenge and take the lead in establishing a culture for change.
- This leadership challenge includes commitment and active involvement in speech and action. The role of the leader is to lead through example everyday, with more than just "lip service."

Total Quality Management Infrastructure

Quality Management Boards (QMBs)

- Include a senior member.
- Identify improvement opportunities within issue areas.
- Are responsible for changing processes when change is needed.
- Remove barriers.
- Establish Process Action Team (PATs) and facilitate progress.
- Provide TQM leadership.

TQM Review

- *Quality Management Boards (QMBs)* include a senior member. Members are appointed based on issue-area expertise and responsibility.
- The QMBs at each level identify improvement opportunities within issue areas. QMB members have the responsibility and authority to change processes when change is needed.
- The functions of QMBs include:
  - Identifying processes in assigned issue areas
  - Prioritizing processes by improvement potential
  - Analyzing and changing processes when change is needed
  - Removing barriers
  - Establishing Process Action Teams (PATs) when appropriate
  - Facilitating progress of PATs
  - Initiating action on problems referred by PATs
  - Providing TQM leadership.

Total Quality Managment Infrastructure

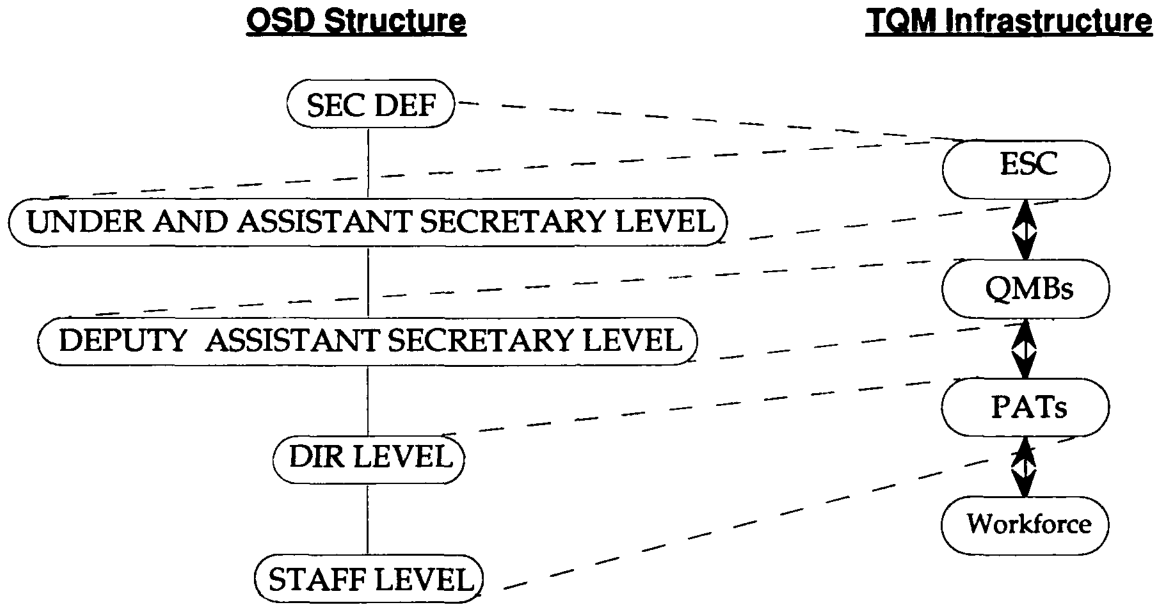
Process Action Teams (PATs)

- PATs are formed to deal with specific process problems and to resolve issues.
- Roles of QMBs and PATs are complementary.
- QMBs focus on more permanent and larger issues than those addressed by PATs.
- Involving many people in the improvement process is critical to making the QMB/PAT structure work.

TQM Review

- The main agenda of PATs is to improve a work process that an ESC or QMB has identified as important to change. The PAT studies the process methodically to find permanent solutions to problems.

TQM and the OSD Structure



TQM Review

- The above graphic shows how the TQM infrastructure is imposed on the organizational structure of the Office of the Secretary of Defense (OSD). This infrastructure provides a conduit for increasing cross-functional teaming arrangements to accomplish study, thinking, and decision making about quality improvement in all aspects of the organization's activities.

- The TQM infrastructure is designed to effectively flatten the organizational structure. It promotes an "ad hoc" climate (not an ad hoc approach) that encourages making improvements and provides easier access to top management to gain their support for process improvement.

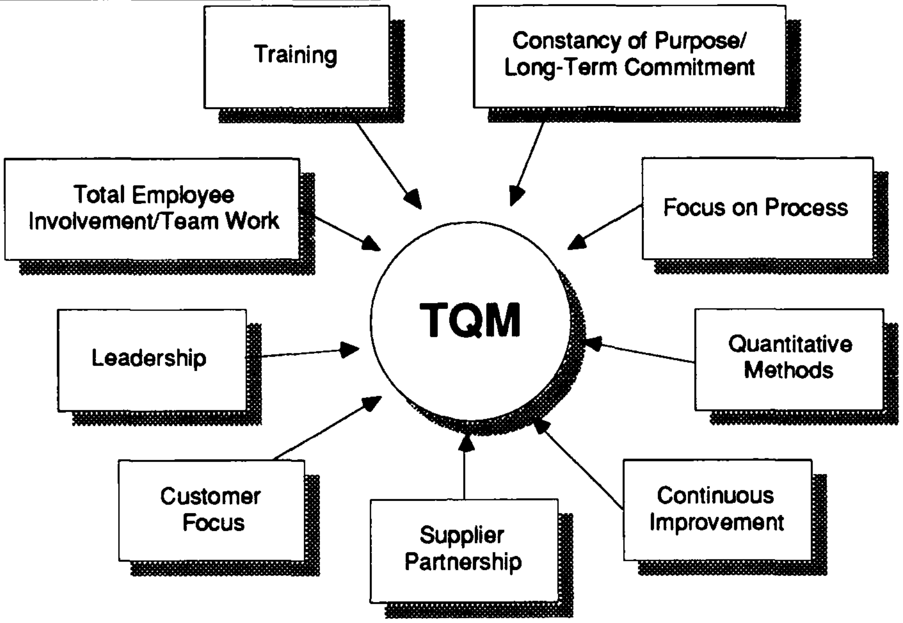
- The existing organizational structure also has the capacity to surface issues to top leadership. However, its functional nature makes it more difficult to create cross-functional teaming arrangements. The structure, not the people in it, fosters processes that are not oriented toward continuous improvement.

- The complex nature of the OSD organizational structure makes it difficult to move the "administrative machine" to a decision point. Two principle reasons account for this difficulty:

    - The administrative process for getting the leadership to a readiness condition for decision making absorbs a majority of the the supporting staff's energy and effort.

    - The functional nature of the organization tends to cloud the "grand vision" needed for important issues, and there is a resulting tendency toward sub-optimizing in problem analysis.

TQM Elements



TQM Review

- Quality management has emerged as a fourth generation management style to replace the most commonly used management style of today – management by results.

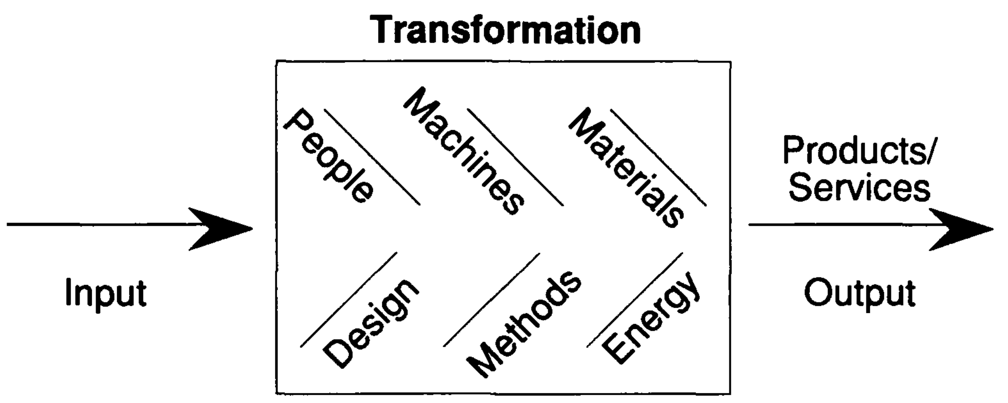
- Quality management provides the method, often lacking in management by results, to continuously improve each and every process in an organization. This philosophy combines human resource management techniques and quantitative methods to focus on:

  - Supplier
  - Internal processes
  - Customer.

- Quality management can be represented by the nine basic elements illustrated above.

- This course focuses on the quantitative methods to study and continuously improve work processes to deliver better results.

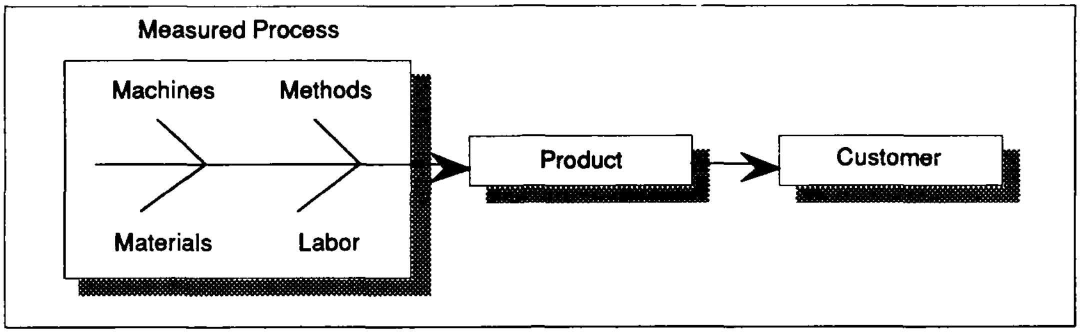
Focus on Process



TQM Review

- One element of TQM is the *focus on process.*
- A process transforms something.
- A process has a ***supplier***, ***processor***, and ***customer***.
- In a process, some item, information, or person is acted upon in order to be changed. The resulting change, or outcome, is the reason the process exists.
  - An event is transformed by a reporter into copy for an article.
  - A candidate is transformed by a placement process into a new hire.
  - A piece of metal is transformed into a device.
- The inputs into a process are transformed through people, machines, materials, design, methods, and energy to produce a product or service.

Focus on Process



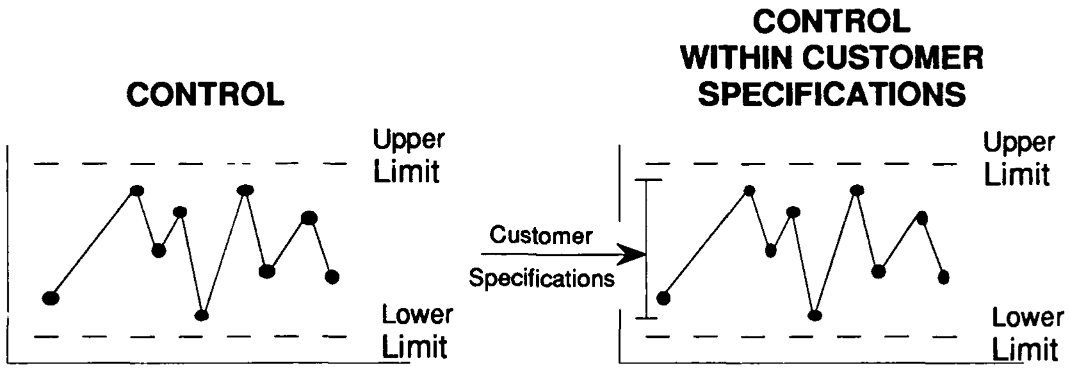
- Focuses on the processes by which work gets done, rather than on a hierarchy of individual accountability.
- Provides the methods to study and improve processes for better results.

TQM Review

- TQM has emerged in successful American and Japanese corporations as an approach to produce quality products and remain competitive.
- TQM *focuses on the processes* by which work gets done, rather than on a hierarchy of individual accountability.
- TQM is a method for continuous improvement of processes. *Quantitative methods* are used to study work processes and develop better methods to deliver better results.
- *While management by results demands better results from the current system, quality management provides the methods to study and improve processes for better results.*

Focus on Process

Process Control



TQM Review

- Every process contains variation. Determining the causes of process variation is an important part of controlling variation. There are two types of causes of process variation: common causes and special causes.
  - *Common causes* result from natural fluctuation in the process. Common causes can be affected only by management's changing the process.
  - *Special causes* are unusual circumstances or events that are not due to natural fluctuation in the process.
- A process is in *control* if it is stable or predictable, that is, if variation is due to common causes, not special causes.
  - Managers need a stable system as a basis for prediction. With a stable system, managers can plan an average with a high degree of belief.

- Management is responsible for getting processes in control. A change in method, operator expertise, or equipment may be needed to stabilize the process.

- A process can be stable and predictable, but not necessarily acceptable.

- In addition to being in control, the process must be able to consistently produce within the customer's specifications. If a process does not produce within the specified requirements, then management has to find a different process or modify the specifications.

- A process is improved to:

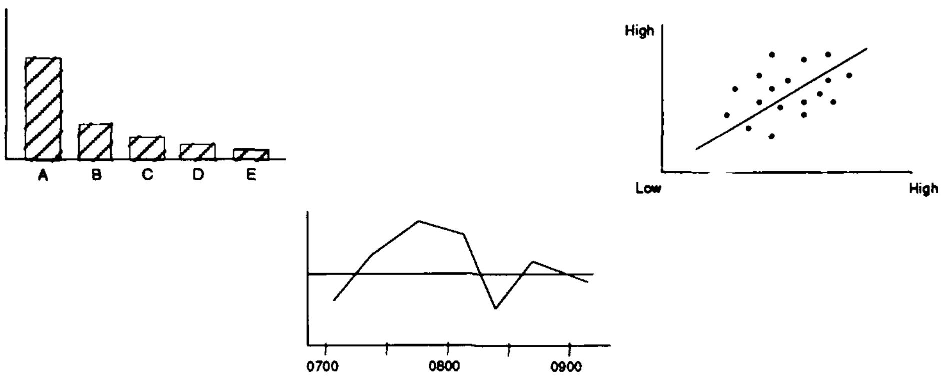
  - Reduce process variation, thereby reducing variation in output (bring the process into control).

  - Move the process average to a higher or lower level to meet specifications and customer needs.

Reference:

Deming, W. Edwards; Out of the Crisis; MIT Center for Advanced Engineering Study, Cambridge, MA, 1986.

Quantitative Methods



- Identify problems
- Identify solutions
- Monitor progress

Data-based decision making

TQM Review

- Total Quality Management integrates statistical thinking and management actions and provides managers with the facts necessary for data-based decision making. Managers no longer have to rely on instinct or intuition to make decisions.

- Quantitative methods are used to:

  - Identify problems, not symptoms or signals
  - Identify permanent solutions
  - Monitor the progress of improvement and process experiments.

- Managers and employees need to develop the skills to enable them to scientifically study and constantly improve every process by which work is accomplished.

Group Discussion

THAT WAS THEN...

...THIS IS NOW

- What have you done to improve quality since awareness training?
- Have you seen TQM activity in your work place?

TQM Review

- What types of things did you try?
- What were some of the successes?
- What were some of the set backs?
- What were some of the obstacles?

TQM Review

- What kind of TQM activity in other functional areas did you see?

- What kinds of quantitative tools have you used or seen used as part of a TQM activity?

- What actions will you take to the improve probability of success in your next effort?

- Be prepared to present your experiences to the group.

- The Awareness Course was developed with the objective of making OSD personnel aware of TQM concepts. This course will take you beyond the awareness stage by introducing you to specific quantitative methods used to implement TQM. The goal of this course is to present problem solving skills using statistical thinking and methods that will assist you in process evaluation and improvement. The following module reviews basic statistical principles that will help you use quantitative methods.

MODULE TWO

SCIENTIFIC METHOD AND THE PLAN, DO, CHECK, ACT CYCLE

Module Two Objectives

Upon completion of this module, the participant will be able to:

- Describe the scientific method of inquiry.
- Compare and contrast the Plan, Do, Check, Act (PDCA) cycle with the scientific method.
- Describe the purpose and focus of the Plan, Do, Check, Act (PDCA) cycle.
- Describe the steps in the Plan phase.
- Explain the use of operational definitions in the PDCA cycle.
- Explain the activities in the Do phase.
- Describe the method for structuring the data collection process.
- Identify the purposes of analysis in the Check phase.
- Describe the activities involved in the Act phase.
- List the tools for continuous process improvement used in the PDCA cycle.

Scientific Method and the Plan, Do, Check, Act Cycle

- The basis for this module is the Plan, Do, Check, Act Cycle. It is frequently called the Shewhart Cycle because it is an adaption of Walter Shewhart's thinking. Shewhart was a pioneer in quality control using quantitative methods.

- The above listed learning objectives for this module are designed to give you an understanding of how the PDCA cycle is related to the scientific method, and why it is necessary to apply scientific methods to the study of problems if one desires to reach real solutions.

- Scientific method is, without question, the most essential aspect in the approach to problem solving. Often when organizations are faced with problems, there is a tendency to start measuring everything in a hope that something will turn up to suggest a solution. It rarely ever happens that way!

Scientific Method

- Explain
- Predict
- Control

$\Big\}$ Objectively

Scientific Method and the Plan, Do, Check, Act Cycle

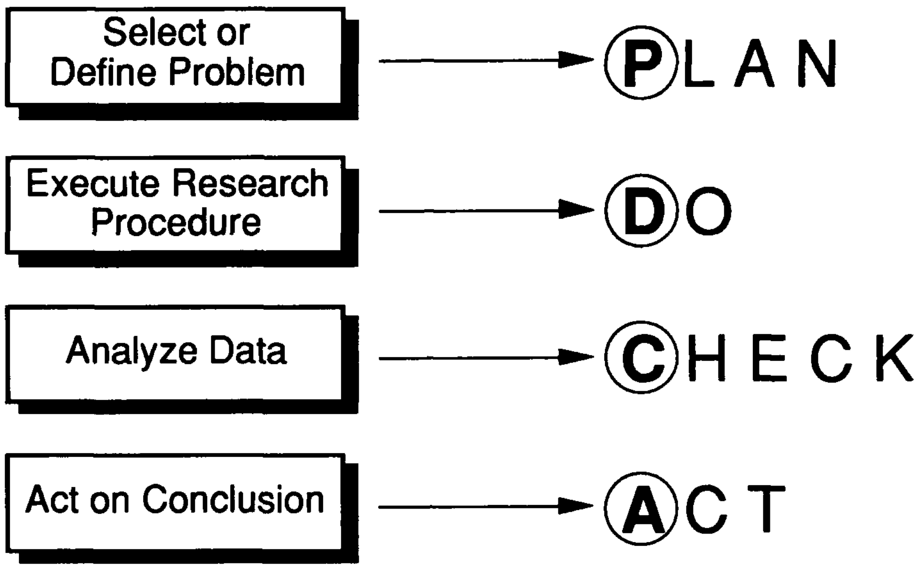
- The scientific method of inquiry is used to explain, predict, or control some specific phenomenon.
- The key to the scientific method is acquiring knowledge, which is accomplished through the testing of ideas and theories.
- Research employing the scientific method is formal and systematic.
- The scientific method involves a sequence of steps that lead to a better understanding of the phenomenon under investigation. In applying the scientific method, the emphasis is always on objectivity.
- It is not always easy to get acceptance for applying the scientific method of problem solving. It tends to take more time and requires gathering data and doing analysis. Additionally, for all difficult problems there are always several well meaning people who have at hand the simple and obvious solution, which is often wrong!

Scientific Method and the Plan, Do, Check, Act Cycle

- The scientific method does not accept experience or authority as a basis for proof. The purpose of research is not to make a case for a given position – position papers do that! Research is the quest for truth – unbiased, objective study that can be replicated.

- Moving toward a quality emphasis requires the discipline of the scientific method, not the erratic, unreasoned reactions of the uninformed who are "focused on fixing" but have little idea of what the problems are. As you will learn when we discuss management tampering, a short-term solution is frequently a contradiction in terms.

Scientific Method and PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- In TQM, we use a scientific method to guide process improvement activities. This scientific method is referred to as the Plan, Do, Check, Act (PDCA) Cycle, also referred to as the Shewhart Cycle of Learning.

- The PDCA cycle provides the model to "manage quality" into a process and the resultant outcomes by providing *objective* information to *explain*, *predict*, and *control* the *process*.

- The PDCA Cycle is somewhat different from pure research and this difference is important. In pure research, rigid controls are applied to limit the number of variables ideally to an independent and a dependent variable. The PDCA cycle is applied in the work place where the variables cannot always be controlled to the extent they are in pure research. In applying the PDCA cycle, the emphasis is on identifying variables and determining which are the most vital in the process under investigation. After identifying the important variables, they are manipulated in a controlled way to achieve process improvements.

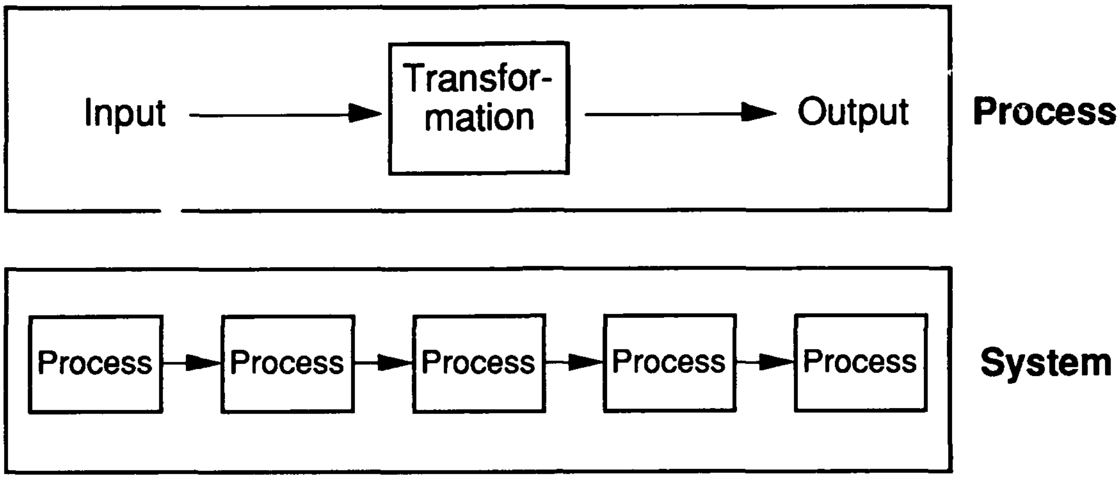
Scientific Method and the Plan, Do, Check, Act Cycle

- PDCA is best defined as applied research, where the emphasis is on getting things to work well, without being overly concerned about the theoretical foundation. The real value of the PDCA approach is that it encourages practical problem analysis by people who are knowledgeable about a given process.

- Before going into more detail about PDCA, it is necessary to have a clear understanding of what constitutes a process and how processes are linked together to form systems.

PDCA Cycle

Focus on Process Improvement



Scientific Method and the Plan, Do, Check, Act Cycle

- The PDCA Cycle is directed at process improvement. To appropriately manage the improvement process, it is important to understand the distinction between a process and a system.
- A *process* consists of *inputs*, a *transformation* of the inputs (through machines, methods, materials, labor, information, or environment), and a desired outcome or *output*.
- A *system* is a complex *collection of processes*. Inherent in a system is the transaction process for handling communication and interaction between and among the individual output processes of the system. The more output processes there are in a system, the more critical and complex becomes the transactional process.

- Remember that the PDCA cycle focuses on *process improvement.*

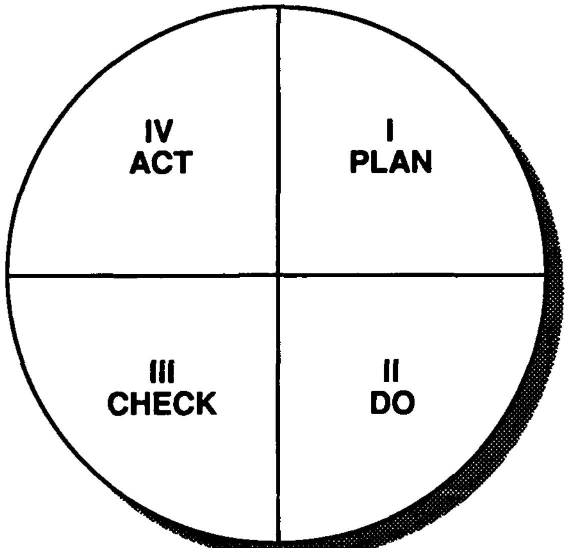
  - It is important to *distinguish and isolate a process from the system.* By focusing on a single process, you can identify the inputs, outputs, and variables of the process. Focusing on a single process also helps you manage the improvement process.

  - Every process is part of a system, and you need to be sensitive to the *interrelationships* among processes within a system.

- *System improvement* results by steadily improving individual processes and also improving the transaction process that handles interaction.

PDCA Cycle

Managing Process Improvement



Scientific Method and the Plan, Do, Check, Act Cycle

- As was previously discussed the PDCA Cycle is a four-step scientific method for managing continuous process improvement.

- The first step is to "Plan" a change. Planning includes:

  - Analyzing the status quo
  - Developing operational definitions
  - Identifying measures of merit
  - Baselining
  - Identifying target improvement areas
  - Determining key questions.

  This step requires knowledge of the subject matter, the customer needs, and the process.

Scientific Method and the Plan, Do, Check, Act Cycle

- The next step is to "Do" or test the change, preferably on a small scale. This step includes:

  - Validating the process description
  - Identifying potential causes
  - Establishing process measures
  - Developing a data collection plan
  - Collecting data
  - Testing your hypothesis.

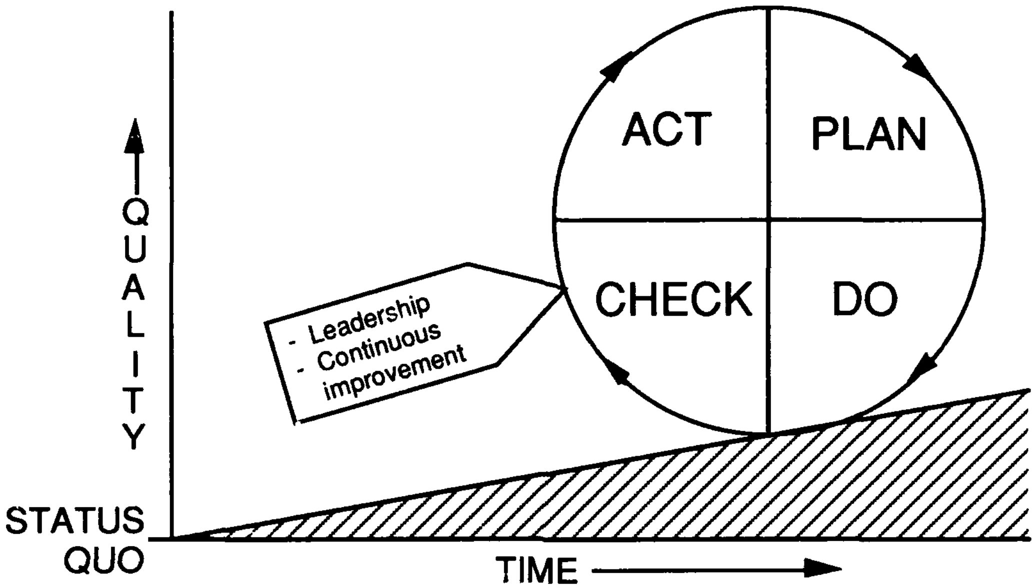
- The third step is to "Check" or study the results – what did we learn. Quantitative methods are used to analyze the data. The resultant information is used for planning and predicting.

- The final step in the Shewhart Learning Cycle is to "Act." Action options include:

  - Adopting the change
  - Experimenting again with different environmental conditions and/or people to extend the boundary of knowledge.

- Each phase of the cycle will be described in more detail in this module.

PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- The PDCA Cycle can be envisioned as the hub in the wheel of quality that should always be moving toward improvement. All quality activity originates from the hub, and a good portion of this activity calls for gathering data and applying quantitative methods to assist in process analysis.

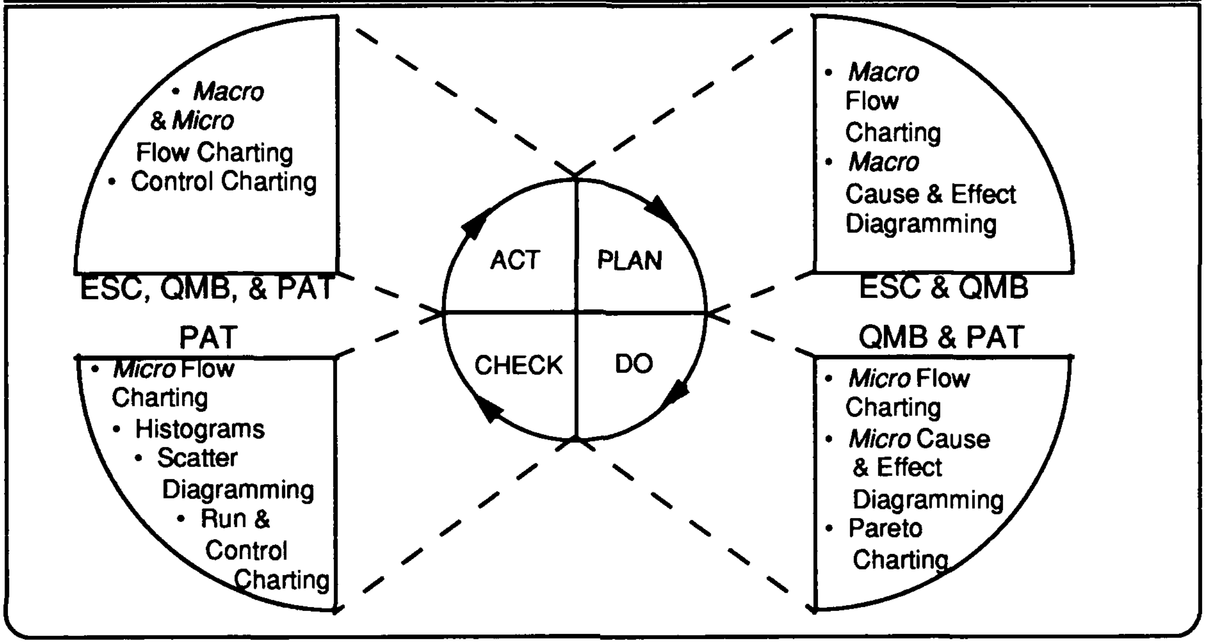
- PDCA is a useful model for achieving quality process improvements. Each phase in the cycle applies one or more of the eight tools that will be taught and practiced in this course:

  1. Flow charting
  2. Cause and effect diagramming
  3. Check sheet recording
  4. Pareto charting
  5. Histograms
  6. Scatter diagramming
  7. Run charting
  8. Control charting.

- The PDCA Cycle is an excellent model and these quantitative methods are excellent tools for arranging information so that it is useful in the analytical process. However, neither the model nor the tools are substitutes for thinking.

- *What to measure* is a more fundamental question than how to measure.
- Finally, the PDCA model cannot be effectively implemented unless there is a TQM infrastructure in place in the organization. Such an infrastructure currently is evolving in DoD, and your participation in this course is evidence that the environment is right to apply the PDCA model to make process improvements.

PDCA Cycle

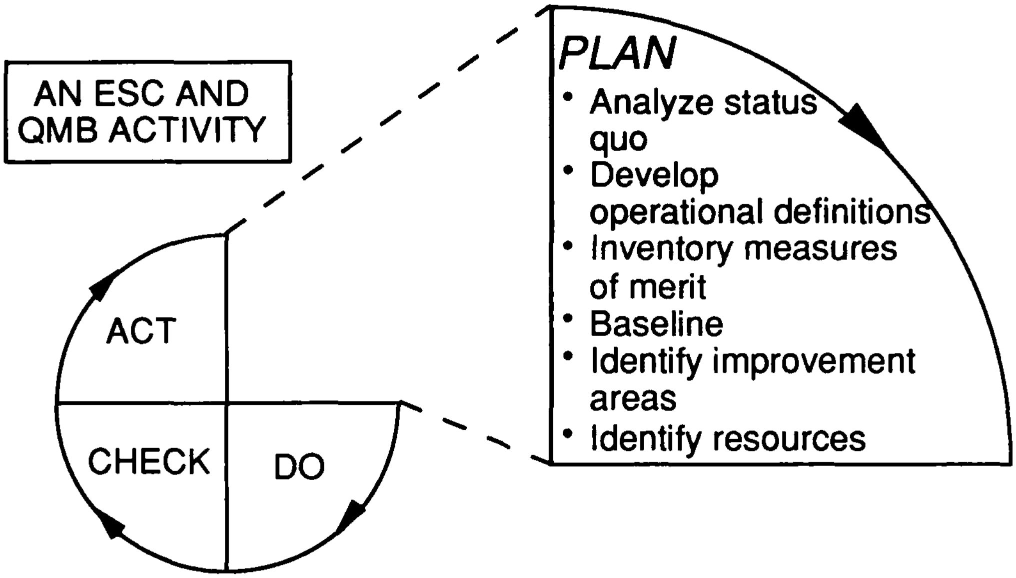


Scientific Method and the Plan, Do, Check, Act Cycle

- The above graphic presents a general overview of when the quantitative tools should be employed in the PDCA cycle.
- In the Planning phase, the ESC and QMBs are concerned with the *macro* (larger) perspective and relating the vision and mission of the organization to the planning activity.
- In the Do phase, the QMBs and PATs go into more detailed (*micro*) analysis and begin to structure how the improvement activity will be accomplished.
- In the Check phase the tools are used to document how well the improvement activity is doing in a limited application. This is primarily a PAT activity.
- In the act phase, the emphasis is on overall implementation and ensuring that the process improvement becomes entrenched in the generally accepted practices of the organization
- The application of flow charting in all phases of the PDCA cycle is especially

important in the knowledge work environment. Knowledge workers have to understand the interrelationships among their different areas of responsibilities. Additionally, the cooperation and coordination involved in knowledge work processes are especially sensitive to relationships that are usually more complex than formal descriptions of how functional entities interact. Constant attention needs to be given to having an accurate and dynamic representation of how things get done.

Planning in the PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- The planning phase of the PDCA Cycle is the most important phase. The following are the key steps in the planning phase:

  - Identify how things are actually being done.

  - Compare how things are actually being done with how they are supposed to be done (what the rules and directives say). Document the differences.

  - Do a terminology inventory and document operational definitions in use.

  - Do a measures of merit inventory. What is considered important to the customers? What is considered important in the organization? What measures have been communicated to suppliers?

  - Do a personnel skills inventory. What skills do employees have and what skills do they need for their jobs?

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  - Do a measures of merit inventory. What is considered important to the customers? What is considered important in the organization? What measures have been communicated to suppliers?

  - Do a personnel skills inventory. What skills do employees have and what skills do they need for their jobs?

  - Baseline your activity. Compare how similar organizations operate. Document where performance emulation is desirable.

  - Deliberate on the data obtained from the above activity. Identify a significant process that shows the greatest promise for improvement.

- The planning phase of the PDCA is labor intensive and can be seen as threatening to the organization because there will be a lot of activity with little evidence that any change is taking place. During the planning, the top leadership must be reassuring and visible. Planning should be presented as "taking stock." While most of the planning activity is accomplished by the executive steering committee and the quality management boards, everyone should be invited to provide input. Information about the planning activity should be released on a regular basis. The plan phase is <u>not</u> the time to introduce change, no matter how apparent it may be that change is needed.

- The outcomes of the planning phase should be:

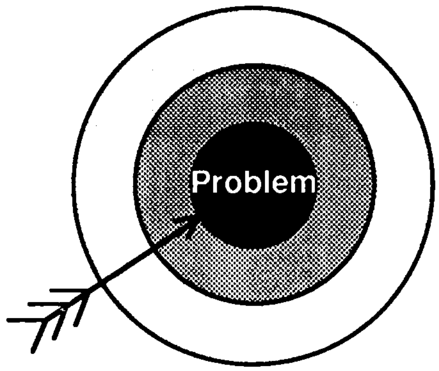
  - A statement of the problem.

  - A better understanding of how current processes are operating.

  - A substantial data base to assist in answering questions and identifying which process will be earmarked for improvement.

Planning in the PDCA Cycle

Identify and Define Problem



Target Problem

Tools:

- Flow Chart
- Cause and Effect Diagram

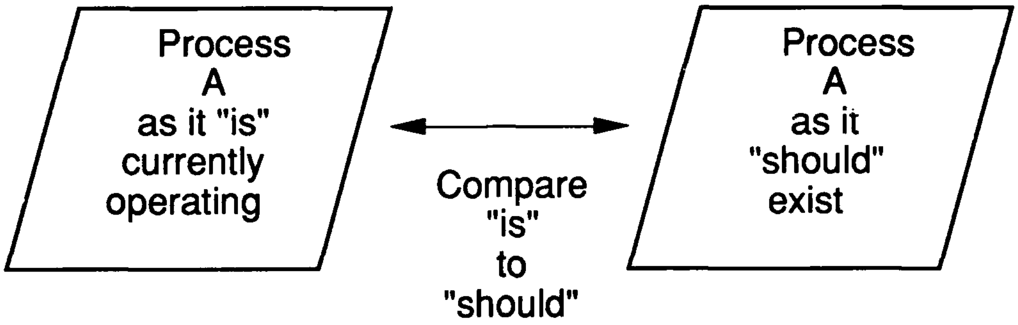
Scientific Method and the Plan, Do, Check, Act Cycle

- *Identifying and defining the problem* is a difficult task. Care must be taken in selecting the problem so that it does not incorrectly infer any unproven relationships. For example, consider a proposal to research the problem of determining the amount of bonus payment that would be effective in retaining military personnel. This would be an inappropriate problem statement because it implies a positive relationship between bonus payments and personnel retention that may not be true. In this case, the problem is focused on the system of personnel management.

- It is also necessary to *properly bound the problem.* Otherwise, the size of the experiment may get out of hand, and it may be impossible to carry out the project due to budget and time constraints. In the personnel/retention example, the problem statement is beyond the scope of a process, and addresses a system of personnel management. In this case, it would be more appropriate to *break out one of the processes* in the personnel management system and subject it to analysis.

Planning in the PDCA Cycle

Baseline Activity



Understanding Existing Processes

Scientific Method and the Plan, Do, Check, Act Cycle

- Considerable attention needs to be given to clarifying the status quo.
- Compare how things are actually being done to how they are supposed to be done (what the rules and directives say). Document the differences.
- Baselining is both an internal and an external process. Internally, the *operation of processes* under consideration for PDCA analysis must be outlined to ensure that they are well understood, and measured in their operating state to determine if they demonstrate characteristics of being in control. Process control will be explained in more detail later in the course.
- External baselining involves going outside the organization to examine how similar processes are functioning and what innovations may be evident in the way work is getting done.

Planning in the PDCA Cycle

State Improvement Objectives and Measures of Performance

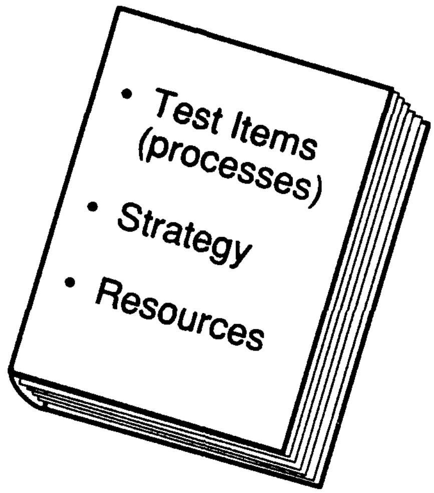
- Identify customer/supplier relations
- Determine customer needs (operational definitions)
- Identify measures of merit
- Develop improvement objectives

Scientific Method and the Plan, Do, Check, Act Cycle

- First identify *customers* and *suppliers* and how they *relate* to each other.
- Establish close rapport customers and suppliers to develop *operational definitions of needs.* Common terminology is a very important part of process improvement.
- Do a measures of merit inventory. What is considered important to the customers? What is considered important to the organization? What measures have been communicated to suppliers?
- Where problems are identified by customers, possible cause factors should be identified for consideration in the planning phase of the PDCA Cycle.
- Finally, develop improvement objectives. Determine how to go from where you are to where your customer wants you to be.

Planning in the PDCA Cycle

Design Research Plan



Scientific Method and the Plan, Do, Check, Act Cycle

- The *research plan* provides the *guidance* to direct the Do, Check, and Act phases of the PDCA Cycle. It is the roadmap for improvement.

- *Selecting subjects/test items (processes)* involves identifying the target processes and the sampling methods, because testing the whole population is rarely possible. Selecting the sample also involves steps to ensure randomness for avoiding bias in the experiment. The measuring instruments for the experiment also must be capable of detecting differences in process variation in the range called for by the experiment.

- The research plan should identify the general sampling method. Sampling plans are discussed is more detail in Module Three – Statistical Theory and Tools.

- *Developing strategies.* For example, will the research be conducted as a field experiment (controlled natural setting), field study (minimal control in natural setting), or as a sample survey (standardized data collection)? The strategy should also include a study schedule. The data collection plan and procedures are part of the Do phase.

- *Identifying resources.* Identify the types and level of resources required to accomplish the strategy. This includes identifying:

  - Process Action Team (PAT) membership

    -- Qualification for selection
    -- Level of effort

  - Training requirements

  - Support requirements.

Group Discussion

PLANNING IN THE PDCA CYCLE

Scientific Method and the Plan, Do, Check, Act Cycle

- Congress frequently requests information from OSD, and these requests are given high priority in terms of staff time devoted to providing thorough and prompt responses.
- Congressional inquiries are usually handled in a formal way, and responses must be approved by the top leadership in OSD.
- You will now participate in an exercise to plan for an improvement in the administrative system for handling congressional inquiries in OSD.

Group Discussion: Planning in the PDCA Cycle

Scenario: You are asked to participate in the planning phase for making improvements in the administrative system used in OSD for responding to congressional inquiries.

Discussion Questions:

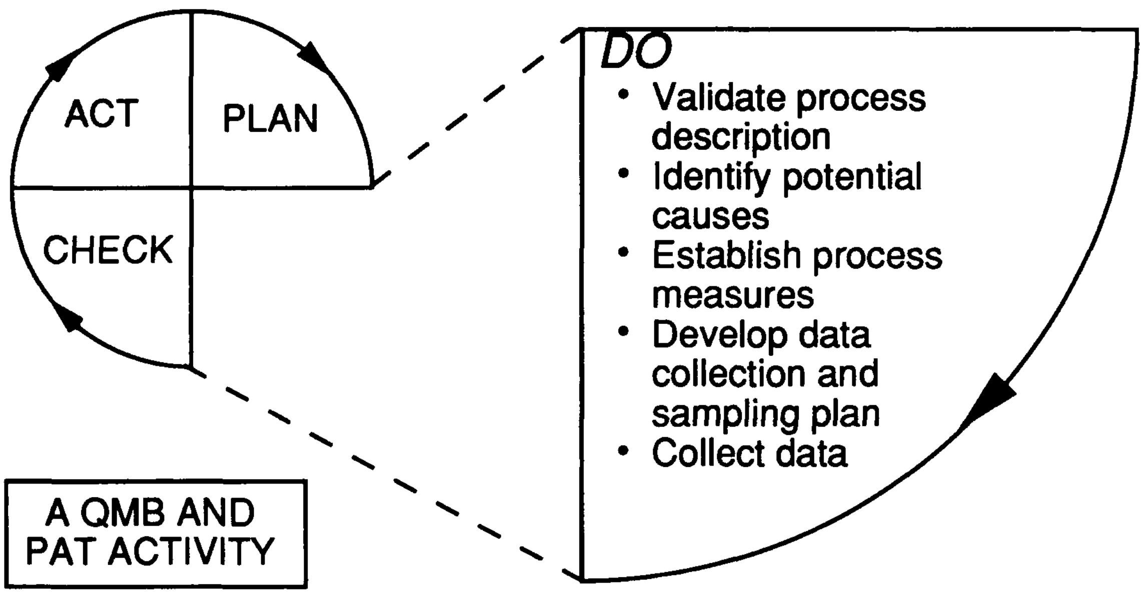
1. What process within the administrative system would you identify as offering the best opportunity for improvement?

2. How would you develop a plan?

3. What operational definitions would you use?

4. What measures of merit would you identify to judge the effectiveness of the process?

Doing in the PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- The Do phase of the PDCA Cycle is primarily a process action team (PAT) activity with support from the appropriate Quality Management Board (QMB).

- The PAT must concentrate its initial activity on reviewing its QMB charter. All members of the team must have a clear understanding of the goals established for the PAT.

- *Validate process description.* Next, the PAT should carefully review the data available from the Planning phase and validate the process description of how things are currently accomplished. It may be necessary to expand the process description to a more detailed level to examine process steps that are important to consider in the analysis. The tool used for this step is the flow chart, which will be explained and practiced in Module Four.

- *Identify potential causes.* After a detailed flow chart is developed, the PAT team should identify potential causes. This activity is best focused by using cause and effect analysis with the "fishbone" diagram to consider all possible causes of problems in the process. Cause and effect analysis will be explained and practiced in Module Four.

- *Establish process measures.* The PAT must next establish process measures. In this step, operational definitions are developed in great detail so that there is minimum ambiguity when taking process measurements. The following page describes the use of operational definitions.

- *Develop data collection and sampling plan.* The next step is to identify the methods and tools to be employed for gathering the necessary data to answer the key questions. Data must be collected in a systematic manner and properly documented so that they can be validated and replicated if necessary. There is a four-step process for structuring data collection, as described in the following pages.

- *Collect data.* The final step in the Do phase is to collect the data based on the plan. Check sheets are useful tools for organizing data, and will be explained in Module Five.

Scientific Method and PDCA

Operational Definitions

- **Global**
- **Specific**

Scientific Method and the Plan, Do, Check, Act Cycle

- American culture is heterogeneous and words often have several connotations. Therefore, we need to spend a lot of time talking about what we mean. Operational definitions should result in a common understanding of terms.

- *Global.* Recognize the heterogeneous nature of an organization's culture.

  - Terminology has different meanings throughout the organization.
  - Specialized terminology makes common understanding difficult.

- *Specific.* Express ideas and processes in terms of observable and measurable parameters.

Doing in the PDCA Cycle

Specific Operational Definitions

- Specific operational definitions express ideas and processes in terms of observable and measurable parameters.
- Without operational definitions, accurate data collection is impossible.
- Everyone must have a common understanding of an operational definition; everyone does not necessarily have to agree with the definition.
- Operational definitions are best developed through repeated small pilot testing.

Scientific Method and the Plan, Do, Check, Act Cycle

- A specific operational definition describes a variable in terms of how it is measured. For example, a successful "request-for-information" phone call might be operationally defined as one in which the person requesting the information is given the information in a timely manner (less than 5 minutes) on the first call with only one extension transfer.
- It is important to operationally define variables before attempting to study them. If variables are not operationally defined, accurate data collection is impossible.
- The best technique for developing operational definitions is repeated small pilot testing. Subjecting the operational definitions to field testing at the level where the process work is accomplished will correct most of the definition ambiguity. This activity should be accomplished by direct interviews conducted by PAT members. Sending out for staff comments will not get the job done!

- Consider the example from the last exercise. How do process participants view congressional inquiries? Is the operational definition well understood and does it promote the sense of urgency in the staff that is consistent with the priorities established for such correspondence? The only way to determine this is to get out among the staff and get candid comments from the "action personnel" who have to handle congressional inquiries.

Doing in the PDCA Cycle

Data Collection and Sampling Plan

- What kind of data to collect
- Where and how to collect (sampling plan)
- When to collect
- How to protect and archive

Scientific Method and the Plan, Do, Check, Act Cycle

The following paragraphs describe the four-step process for structuring data collection:

1. *Determine the kind of process data to collect.* This determination is usually driven by the results of the cause-effect exercise. For each key cause-effect relation, there should be a data collection requirement. Because most process problems involve multiple variables, there is always the need to address cause-effect interaction. These more complex interactions should be deferred until the initial data are collected and analyzed. From the initial data, it may be possible to identify what interactions need to be measured. Again, using the example of congressional inquiries, the initial collection of data may show that the staff action for developing the response is significantly impacted by factors external to the process, such as administrative personnel calling to check on the progress of work or interested parties seeking first draft copies of the response so that they can stay informed.

2. *Determine where and how the data will be collected.* As much as possible, data collection should be first hand. However, this is always a time consuming and expensive approach, and alternatives such as sending out surveys and data

requests may have to be considered. The use of historical data is also another consideration, but it should only be used if there is no other alternative to determining how the process was operating at some past time.

- For data collection, standardization is the key, as well as practice sessions to ensure that the collection process is well understood. *Standard data collection forms* are a must, especially if a large amount of data must be compiled.

- All process action teams should be assigned computer resources and a person skilled in constructing data collection formats.

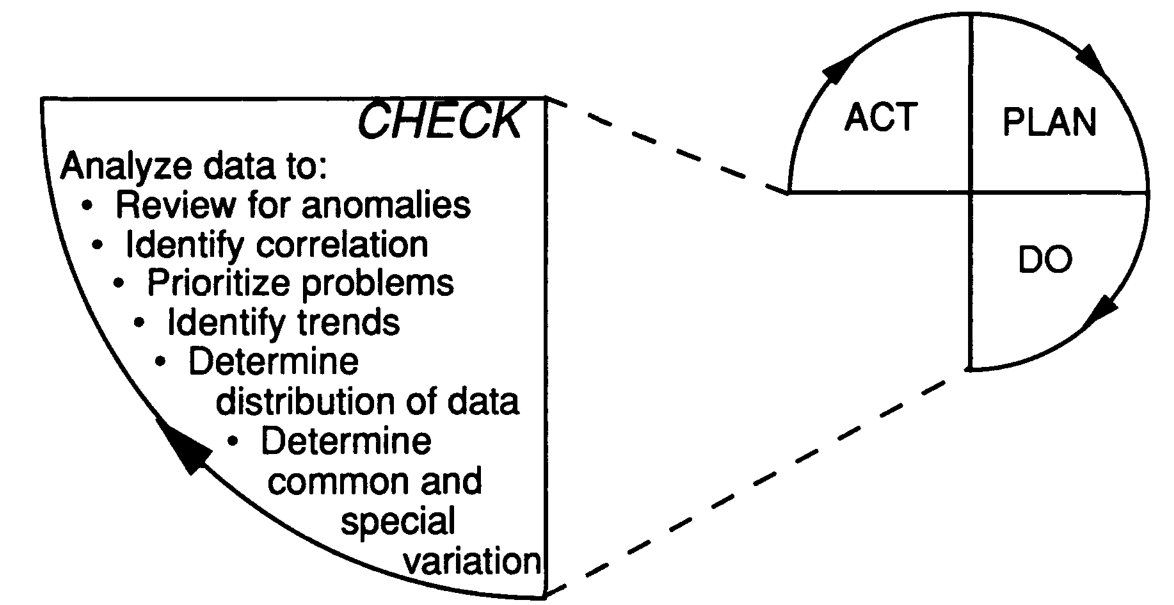
- Another issue in how data will be collected concerns *sampling.* Sampling principles will be dicussed in Module Three.

- The PAT may also want to ensure that it has the services of a researcher trained in statistical methods to aid it in determining when and how data will be collected.

3. *Determine when to collect the data.* The time of day, day of the week, and the month may be significant to the demands on the process under review. The PAT members should be able to map out any calendar cycles that are associated with the process. In the example of congressional inquiries, you could consider collecting data during a period that is representative of the peak demand on the staff for information. Often, the best time to observe a process is when it is under stress. In the congressional inquiry example, the stress level may more likely be associated with the cycle of the budget process, but it could also be associated with key events like base closure studies. Discussions on when to collect data on the process may require the PAT to revisit the flow charting step.

4. *Determine how the data will be protected and archived* for later recall as the PDCA Cycle progresses. Remember, TQM stresses continuous improvement in the processes that produce value-added work. As TQM is adopted and becomes a part of the organization's culture, the PDCA Cycle becomes a value-added process in its own right. This should result in steady improvement in the use of the PDCA Cycle. Each new PAT will be formed to investigate problems that could be quite different from the previous PAT's activity. However, previous methodologies and data collection processes will usually serve as a useful analog for the new PAT.

Checking in the PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- In the Check phase, the Process Action Team (PAT) analyzes the results from the data gathering in the Do phase.

- The Check cycle must begin with a *review of any anomalies* that occurred in the data gathering process that might call into question the validity of the data. These anomalies include any unexpected conditions and observations that would influence how the process might need to be changed. Properly planned data gathering usually includes several pilot efforts to iron out anomalies and the procedures. However, this preliminary effort does not always prevent some unexpected influence or contamination from distorting the data collected.

- Often the results of the Check phase lead you back to the Plan and Do phases. In fact, usually several Plan-Do-Check rounds are required before you can move on to the Act phase.

- Using the congressional inquiry example again, the data collection could easily be contaminated by some nondefense-related political issue that diverted congressional attention and caused a substantial reduction in the number of

inquiries at the time the data were being gathered. If the data are influenced by an anomaly, there are only two choices open to the PAT: collect new data or accept the contaminated data and make a judgement on their implications. In any written report, the anomaly should be clearly explained.

- The Check phase of the PDCA Cycle is long on *analysis*. It is the "heavy thinking" portion of the cycle. It is also the phase with the greatest danger for the PAT members to be victimized by their experience.

  - The results of the data gathering may contradict intuition and previous experiences.

  - The data may be replete with unexpected instruction that could go unacknowledged because of a lack of openness to change and innovation.

- PATs should not always be looking for great leaps forward. Most of the process improvements identified in a PDCA Cycle will be incremental gains from adjustments to how things are already being done. However, PAT members have to be willing to recognize that in the Check phase all things are possible, including the conclusion that things could get done better by a dramatically different process.

- The PAT should receive training in paradigm shifts to help with awareness about the nature of innovation. The team should plan to frequently discuss this matter and be reminded that:

"The greatest obstacle to progress is not ignorance,
but the illusion of knowledge."

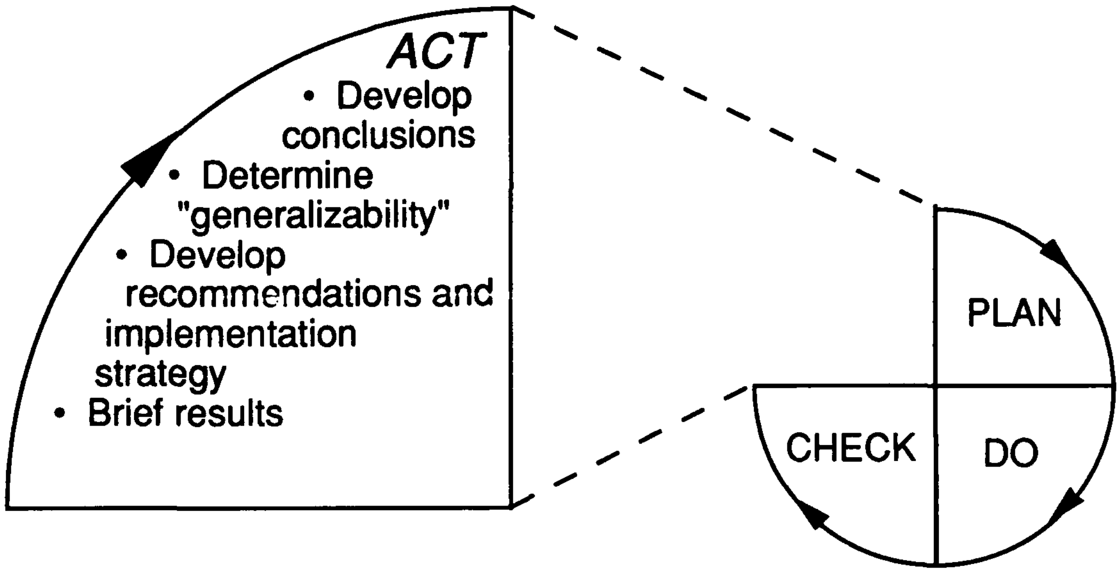
Checking in the PDCA Cycle

PURPOSE	TOOL
• Prioritize Problems	→ Pareto Chart
• Determine Distribution of Data	→ Histogram
• Identify Correlations	→ Scatter Diagram
• Identify Trends	→ Run Chart
• Determine Common and Special Causes of Variation	→ Control Chart

Scientific Method and the Plan, Do, Check, Act Cycle

- There are a number of tools available to assist in the analysis of the data in the Check phase. This chart identifies different purposes of analysis and the tool that can be used for each purpose.
- These tools are described in Modules Five and Six.

Acting in the PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- In the Act phase, the PAT determines what to do next, that is, it acts based on analysis of the data. Action options include:
  - Adopting the change
  - Experimenting again with different conditions and/or people to extend the boundary of knowledge.
- The first step is to *develop conclusions* based on the problem statement, customer needs, and analysis of the data.
- Next, *determine the "generalizability"* of conclusions. How applicable are the test results to the entire organization?
- The next step is to *develop recommendations and an implementation strategy* based on the conclusions. Should a change be adopted, or do you need to study the problem again under different conditions? Make sure your recommendations are substantiated by the data and are consistent with the conclusions. If you

recommend to adopt a change, develop an implementation strategy that includes such items as:

- Training requirements
- Communication requirements
- Workload distribution impacts
- Equipment requirements
- Changes to current procedures or directives
- Schedule constraints or other time constraints
- Transition requirements
- Resource and cost requirements or implications (introduce this last -- emphasize quality first).

• Finally, *develop briefings and reports* to provide feedback to the QMB and ESC. The briefings and reports should contain the following items:

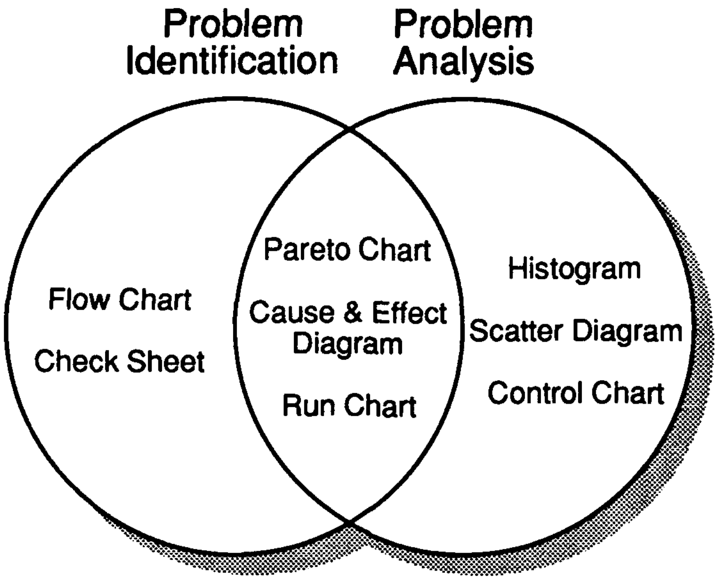
  - Study objectives, including a problem statement, improvement objectives, and performance measure.

  - Study methodology, including a research plan and data collection and sampling plan

  - Findings, conclusions, and "generalizability"

  - Recommendations and an implemetation strategy.

Tools for Continuous Improvement in the PDCA Cycle



Scientific Method and the Plan, Do, Check, Act Cycle

- *"People do not typically think their way into a new way of life; they normally act their way into a new way of thinking. TQM must employ quality tools, techniques, methods, and processes."* -- Scott Sink

- TQM employs problem-solving techniques that provide a rational, logical, and organized way to:

  - Identify problem areas
  - Determine variation in a process
  - Monitor trends
  - Determine the relative importance of problems to be solved
  - Monitor process improvements
  - Assess impacts.

- These tools provide the information necessary for data-based decision making.

Scientific Method and the Plan, Do, Check, Act Cycle

- Throughout the PDCA Cycle, you will continually identify and analyze problems. The above graphic shows how quantitative methods are used in the problem identification and analysis processes.
- Note that some of the tools can be used for both problem identification and analysis in the continuous improvement process.
- The rest of the course focuses on how to construct and apply each of these tools in the PDCA Cycle.

Reference:

Sink, Scott, "TQM: The Next Frontier or Just Another Bandwagon to Jump On?", Quality Productivity and Management, Vol. 7, No. 2, Virginia Productivity Center, 1989.

MODULE THREE

STATISTICAL THEORY AND TOOLS

Module Three Objectives

Upon completion of this module, participants will be able to:

- Explain the distinction between qualitative and quantitative data.
- Explain and contrast ordinal and nominal qualitative data.
- Explain and contrast discrete and continuous quantitative data.
- Calculate three measures of central tendency: mean, mode, and median.
- Analyze DoD data sets and identify the types of data.
- Describe the normal distribution.
- Define two measures of variation: range and standard deviation.
- Calculate the standard deviation of a set of data.
- Analyze sets of DoD quantitative data and calculate mean, median, mode, range, and standard deviation.
- Explain basic sampling techniques.

Statistical Theory and Tools

- It is everyone's responsibility to study and improve work processes scientifically. Managers, however, are ultimately responsible for the performance of a process. To study and improve a process, both managers and employees must understand the concept of variation in a process, and the common and special causes of variation. They also must understand quantitative methods and how to apply them to control and analyze processes for improvement.

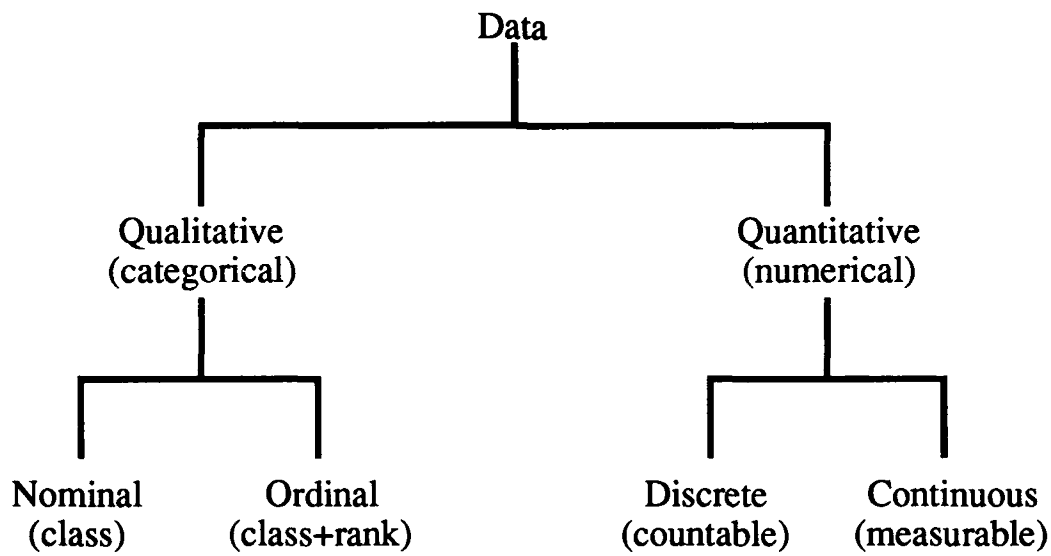
- Quantitative methods provide managers and employees with the tools to identify problems, identify solutions, and monitor progress through data-based decision making.

- The purpose of this module is to provide a general review of some elements of statistical theory and to relate the theory to the use of quantitative methods in Total Quality Management.

- The review of elementary statistical theory will ensure that you have a basis for the analytical tools to be described and used later in the course.

- It is especially important that you thoroughly understand measures of central tendency, the normal distribution, and the use of the standard deviation.

Categories of Data



Statistical Theory and Tools

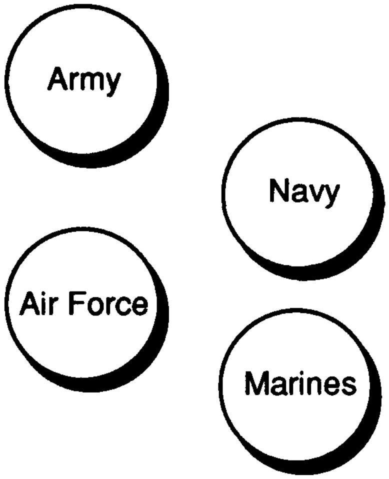
- Data sets (groups of data) used in statistical studies can be so large that the data must be organized and reduced to manageable proportions before they can contribute to a useful study. The methods used to organize and reduce data depend on the category of data being studied.

- The chart above identifies the general categories and subcategories of data. There are two general categories of data: qualitative data and quantitative data.

  - *Qualitative data* are nonnumerical and categorical. Examples of qualitative data are the rank of an individual in the service, the name of a type of aircraft or ship, a functional area of assignment, or a DoD organization. When a type of ship is named, its name characterizes every ship falling into the same type or category. Qualitative data can be used for descriptive purposes but cannot be treated mathematically.

  - *Quantitative data* are data that can be counted and measured. In addition, quantitative data can be treated mathematically to establish relationships that can *infer* cause and effect, probabilities, and levels of confidence.

Qualitative Data



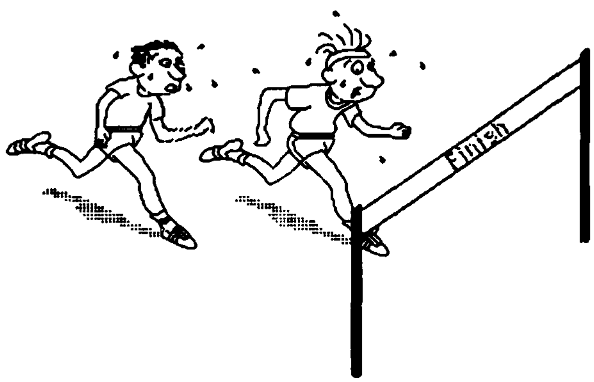
NOMINAL DATA

- Classes or categories of objects
- Cannot be ranked
- Used only for descriptive purposes

Statistical Theory and Tools

- Qualitative data are further categorized as either nominal or ordinal.
- *Nominal data* are classes or categories of objects that cannot be ranked.
- Examples of nominal data are:
  - Names of different aircraft or ships
  - Names associated with military groups, such as Army, Navy, or Air Force categories of services
  - Government employment categories -- Senior Executive Service (SES), General Manager (GM), General Service (GS), and Wage Grade (WG).

Qualitative Data



ORDINAL DATA

- Classes or categories of objects that can be ranked
- No way to distinguish magnitude between data points
- Used only for descriptive purposes

Statistical Theory and Tools

- *Ordinal data* are qualitative data that can be ranked.
- The positions of the finishers of a marathon (for example, 1st and 2nd place) are ordinal data. You should note that although ordinal data can be arranged by position or rank, there is no way to measure a difference in magnitude. The positions of the finishers of a race are ordinal data because they can be ranked but cannot be compared by magnitude; if we know only the positions, we cannot determine how far apart the runners were.
- Another example of ordinal data is assigning priorities to tasks that are to be completed. If you were asked to rank all the tasks you have to complete, the resulting rankings would be ordinal data. Although we can use an ordinal scale to assign priorities to tasks, there is no way to measure differences in magnitude of priority among the various tasks. That is, there is no way of telling how much more important one task is than any other.

- Employee levels within each federal service category are another example of ordinal data. For example, within the General Schedule (GS) category, GS-8, GS-11, and GS-12 represent ordinal data. Although we know there are differences in status and pay among these ranks, it is not possible to distinguish, in any absolute way, differences among the people who hold these different ranks. It is not possible to add subtract, or multiply this type of data. (You may recall that the federal service categories themselves – Senior Executive Service, General Manager, and General Service – are nominal data because they cannot be ranked.)

- Other examples of ordinal data include:

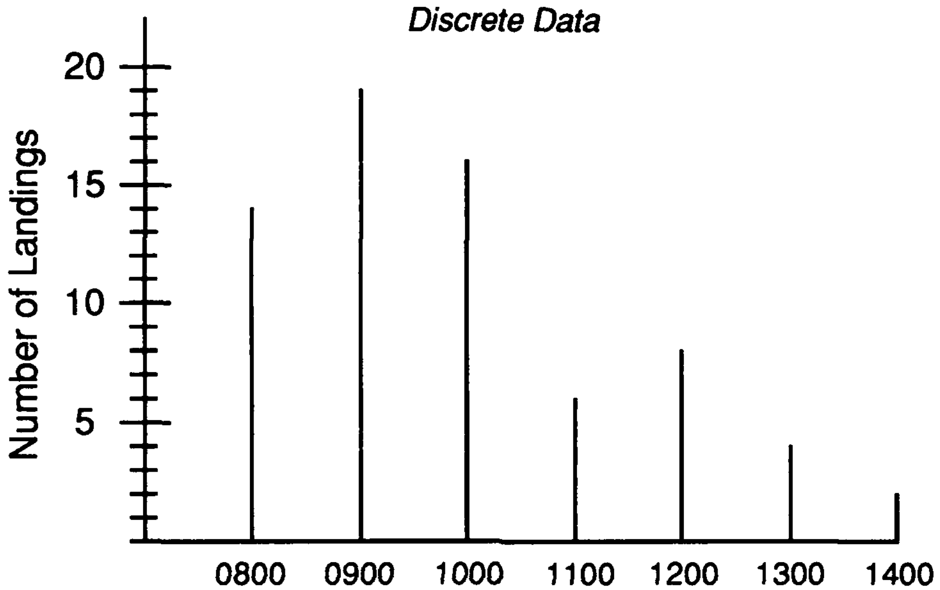
  - Military and civilian ranks

  - The different positions individuals occupy in the hierarchy of a government organization

  - The relative position of a unit in a parade: 1st rank, 2nd rank, etc.

- You should remember that *nominal and ordinal* data can be used only for descriptive purposes; they cannot be treated mathematically.

Quantitative Data



Statistical Theory and Tools

- *Quantitative data* are data that can be counted and measured.

- *Quantitative data* can be divided into two categories: discrete and continuous.

- *Discrete data* are data that can be counted in whole numbers (integers) only. The above graph shows discrete data. Landings are discrete data because they must be measured in increments of one; it is impossible to have half a landing.

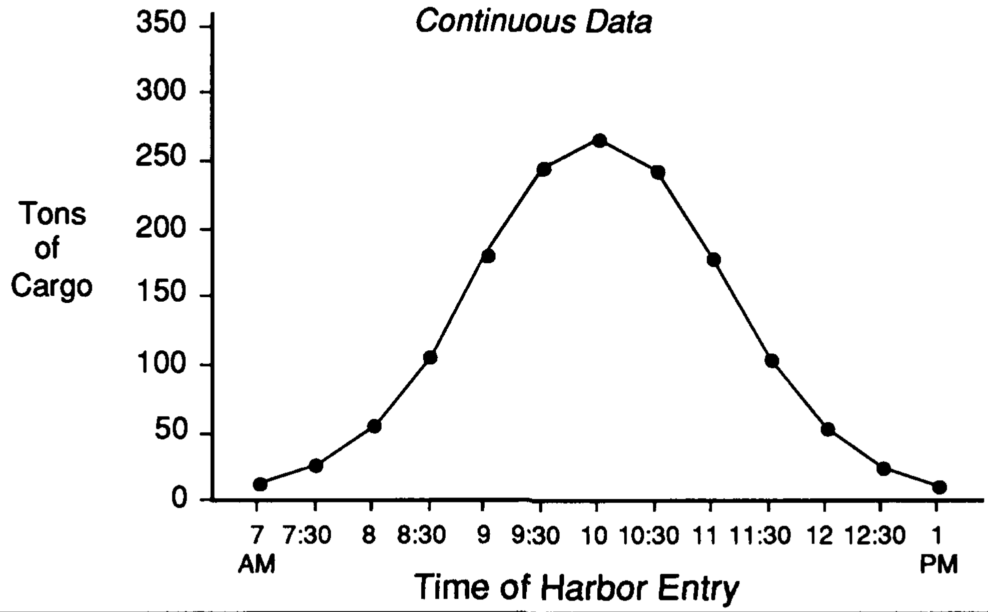
- The number of ships in a fleet, the number of aircraft that land at an airfield in a day, and the number of employees in a government office are other examples of discrete data. Discrete data should not be expressed in fractions, although frequently they are. It is impossible to have 12.5 employees in an office or 15.6 aircraft landing at a field in a day; people and aircraft come in whole numbers.

- Discrete data can be treated mathematically with some qualification. For example, suppose the following data were given for the number of errors on procurement contracts:

Contract #	Number of Errors
1	10
2	6
3	25
4	8
5	11
6	14

It is possible to average this data by summing the number of errors and dividing by the number of contracts. The result would be 12.33 errors. But, of course, a .33 error is not possible. Errors come in whole numbers, not fractions. The number 12.33 may be descriptive, but it is not real.

Quantitative Data



Statistical Theory and Tools

- *Continuous data* are numerical data that are not discrete. These data can fall at any point on a continuum.
- Continuous data permit use of fractions. For example, it is possible to carry a fractional ton of cargo on a ship. Other examples of continuous data are the heights of various people, miles per gallon for different types of cars, and areas of different office spaces. Notice that each of these examples can be expressed in fractions and may take on any one of all possible values.
- It should be noted that continuous data can be measured in whole numbers even though in actuality they occur in fractional values. For instance, suppose that tire tread wear on a group of Army transport vehicles was measured to the nearest mile. Each value will be a whole number; however, the data are continuous because it is possible for the measurements to have fractional parts.

Quantitative Data

Level of Significance

- Measure only to level you need.
- Avoid
  "Measuring with a micrometer,
  Marking with a paint brush,
  Cutting with an axe."

Statistical Theory and Tools

- Level of significance in data collection and manipulation deserves considerable attention early on in any research effort. Gathering data is expensive and time consuming.

- The natural propensity is to collect more information than is necessary in more detail than is necessary.

- You also can get carried away with the specificity of continuous data. For instance, a given scale might be accurate to within .5 pound; however, you don't need to measure to that specificity if measurement to the pound is all the accuracy you need.

- You should be careful about drawing conclusions that don't reflect the accuracy of the data. For example, it is meaningless to attempt to make weight distinctions within .25 pound if the scale used for measuring was only accurate to within .5 pound.

Exercise 3-1

DISTINGUISHING DATA TYPES

Exercise 3-1: Distinguishing Data Types

Scenario 1: The following data represent the tasks and their priorities for three individuals in a DoD division.

Individuals and Tasks by Priority

Individual	Task	Priority
John	Task A	3
	Task B	2
	Task C	1
Sue	Task D	1
	Task E	3
	Task F	2
	Task G	4
Bob	Task H	4
	Task I	1
	Task J	3
	Task K	2

Discussion Questions:

1. What type of data does this table contain, qualitative or quantitative?
2. What subcategory of data does each of the columns represent?
3. Could you average the priorities? If so, would the averages be meaningful?
4. Would it be meaningful to talk of a magnitude of difference between priorities other than a ranking? For example, is Sue's Task D four times more important than Task G?

Exercise 3-1: Distinguishing Data Types

Scenario 2: The data shown below were obtained by determining the number of Soviet submarines in the Mediterranean Sea during twenty weekly periods. Thus, there were ten submarines the first week, 14 the second week, and so on.

Soviet Submarines Operating in the Mediterranean (Weekly)

10	14	12	8	16	9	20	7	11	12
5	9	10	11	16	6	7	17	8	12

Discussion Questions:

1. What general category of data is represented above?
2. What subcategory is represented?
3. Why do the data represent that subcategory?
4. Could you average the data? If so, would it be meaningful for the average to contain a fractional component?

Exercise 3-1: Distinguishing Data Types

Scenario 3: The set of tire wear data below is the average number of miles (in hundreds of miles) of tire wear for various makes of tires on Army transport vehicles. The set of data on aircraft engine washer thickness is the average thickness of a random sample of aircraft engine washers.

Tire Wear (Hundreds of Miles)	**Aircraft Engine Washer Thickness (Inches)**
459	.123
419	.124
375	.126
334	.129
316	.120
305	.132
400	.123
274	.126
350	.128

Discussion Questions:

1. What types of data are represented in the above examples?
2. Are they the same type of data?

Measures of Central Tendency

Tools to summarize or describe the distribution in a data set:

- **Mean**
- **Mode**
- **Median.**

Statistical Theory and Tools

- The next subject to be covered is *measures of central tendency. Measures of central tendency* are ways to summarize or describe the tendency for data to gather around a central point. The measures of central tendency we will discuss are the *mean*, the *mode*, and the *median.*

Measures of Central Tendency

The Mean

$$\mu = \frac{\sum x}{n} = \frac{\text{Sum of all the data points}}{\text{Number of data points}}$$

Statistical Theory and Tools

- The *arithmetic mean*, or average, of a set of quantitative data is equal to the sum of the data points divided by the number of data points contained in the data set. The equation for the mean is shown above.
  - The Greek letter μ (mu – pronounced myōō) is the symbol for the mean.
  - The Greek letter Σ (upper case sigma) is the symbol for summation.
  - x is the symbol for a data point. Σx means the sum of all data points in the data set.
  - n is the symbol for the number of data points in the data set.
- The mean can be thought of as the balance point of a data set. The mean is that score about which deviations in one direction exactly equal deviations in another direction. It is that number about which all the data cluster.

- Example:
    - Calculate the mean of the following five numbers: 5, 3, 8, 5, 6.
    - The mean is the average of the five measurements, that is, (5 + 3 + 8 + 5 + 6)/5 = 5.4
- A second example of calculating the mean is as follows:
    - Suppose you were given the following set of data concerning the amount of flight time in hours logged on an aircraft engine before it had to be removed and replaced.

2300	2500	3000	2000	2345	2678	2467	2100	2900	3100
1900	2112	2540	2890	2400	2470	2690	1990	2345	3200

    - The mean equals the sum of the measurements divided by the number of measurements, which is 49927/20 = 2496.35 hours.
    - You may keep the decimal places or round to the nearest whole number, 2496 hours.
- Be aware that while the mean is a good measure to represent a set of data, data sets can never and should never be represented by one measure alone. Just because you know the mean (average) of a data set doesn't mean (no pun intended) you know much about the data. If, for example, you know that the mean height of eight men is six feet, you might be fooled in your perception of this group's height distribution. It could be that four are eight-feet tall (next generation basketball players) and four are four-feet tall (next generation jockeys.)

Measures of Central Tendency

Mean of Means

20 + 20 + 20 + 20 + 20 = 100	Mean = 20
10 + 10 + 10 + 10 + 10 = 50	Mean = 10
150/10	30/2
Mean of Data = 15 =	Mean of Means = 15

It is acceptable to average means if the data sets are approximately equal in number.

Statistical Theory and Tools

- Suppose you were told that the average years of experience for OSD personnel in acquisition is 10 and the average years of experience for OSD personnel in budgeting is 5. Could you conclude that the average years of experience for both groups is (10 + 5)/2 = 7.5 years? You can conclude that the average years of experience for both groups is the *mean of the means* only if you know that the number of personnel in acquisition is approximately equal to the number in budgeting.

Measures of Central Tendency

Mean of Means

20 + 20 + 20 + 20 + 20 = 100   Mean = 20
10 + 10 + 10 = 30   Mean = 10

$130/8$ → Mean of Data = 16.25 ≠ Mean of Means = 15 ← $30/2$

It is <u>not</u> acceptable to average means if the data sets are not approximately equal in number. If data sets are unequal in number, use a *weighted mean.*

Statistical Theory and Tools

- If you are dealing with groups of averages without knowledge of the number of data points (size of the data groups from which the means were derived), you should not attempt to use a mean of the mean figure.

- Consider the previous example concerning years experience for OSD personnel in acquisition and budgeting. If you know that acquisition has twice as many people as budgeting, you can calculate a *weighted mean*. To calculate a weighted mean, multiply each average by its ratio numeral. Then add the results and divide by the sum of the ratio numerals, as illustrated below.

10 years avg. in acquisition X 2 = 20
5 years avg. in budgeting X 1 = 5
3   $25/3$ = 8.3 avg. years

Measures of Central Tendency

The Mode

Definition:

Data point that occurs most frequently in the data set.

Example:

- The following data represent the number of hours worked in each day in a two-week period. What is the mode?

8	7	9	6	8	10	9
9	5	6	7	9	8	9

- Because it occurs most often, 9 is the mode.

Statistical Theory and Tools

- The mode is the simplest measure of central tendency to calculate. To calculate the mode, simply find the data point that occurs most frequently. With large data sets it often is helpful to arrange the data in ascending order before calculating the mode.

- An example of calculating the mode is described below:

  - Suppose a test was run to see what type of field rations would best suit the armed services. Four types of field rations (of about equal cost) were chosen and sent to various posts for preference testing. The following results were obtained.

Brand	Preference (# of People)
A	11
B	7
C	2
D	6

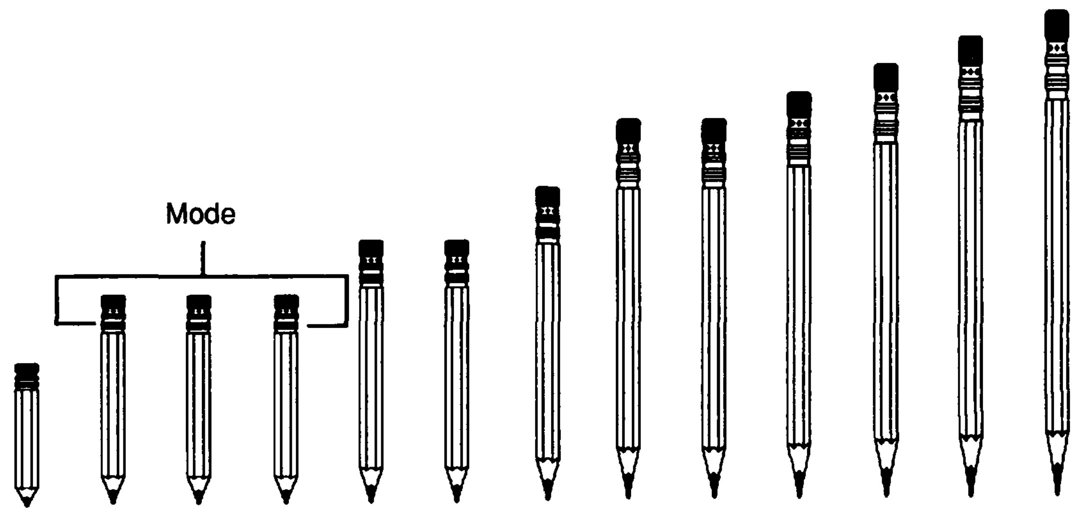
  - What is the mode? The answer is brand A, because it was selected most often.

- Because it emphasizes data concentration, the mode has applications in fields such as marketing, as well as in the description of large data sets collected by state and federal government agencies.

- If a data set contains two data points that occur with equal frequency, and more frequently than all other data points, the set has two modes and is described as *bimodal*.

Measures of Central Tendency

The Mode



Statistical Theory and Tools

- The above graphic further illustrates the mode.

Measures of Central Tendency

The Median

Definition:	*Method:*
The number that splits a data set in two parts such that an equal number of points falls above and below that number.	1. Arrange data in ascending order. 2. Calculate rank of the median = (n + 1)/2. 3. Select the data point in rank position.

Statistical Theory and Tools

- The *median* is the number that splits the data set in half such that half of the numbers are higher than the median and half are lower.

- To find the median, arrange the data from the lowest to the highest value. If the data set is 1, 6, 6, 5, 3, 8, it needs to be rearranged as follows: 1, 3, 5, 6, 6, 8.

- Next, calculate the *rank of the median,* or the location of the median in the data you have arranged from lowest to highest. The rank of median is calculated according to the following equation:

  Rank of the median = (n + 1)/2, where n is the number of data points.

  For this data set, n equals 6. So, (n + 1)/2 = (6 + 1)/2 = 7/2 = 3.5. This means that the median is located halfway between the third and fourth numbers.

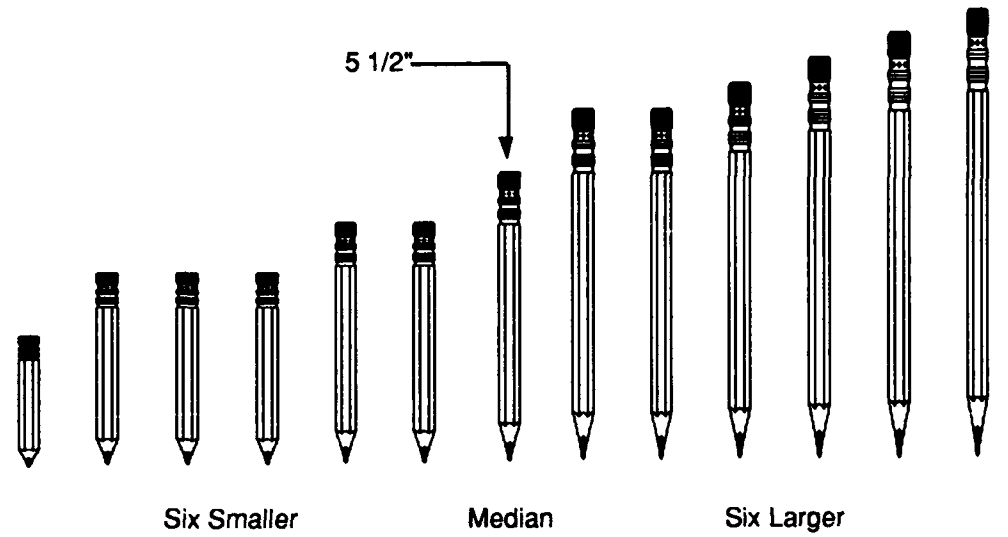
- The reordered data are 1, 3, 5, 6, 6, 8. The third number is 5, the fourth number is 6, and the median lies halfway between these two. Halfway is found by

summing these two numbers and dividing by two. So, (5 + 6)/2 = 11/2 = 5.5, which is the median of this data set.

- Now let's look at a data set that has an odd number of points, such as 1, 3, 5, 6, 8, 10, 14. The number of data points in this set is 7, and the rank of median is (7 +1)/2 = 4. So, the median in this case is the fourth number from the left or right, which is 6.

Measures of Central Tendency

The Median



Statistical Theory and Tools

- The above graphic further illustrates the median.

Measures of Centra! Tendency

Final Points and Reminders

- Each measure of central tendency has advantages and disadvantages.
- Use the measure(s) of central tendency that best reflect(s) the nature of your data.
- Whenever possible, represent the data using all the measures of central tendency.
- Know your data.

Statistical Theory and Tools

- It's important to be careful when using measures of central tendency. The selection depends on the nature of the data. There are advantages and disadvantages to each measure.

Mean

- The *mean* is a valuable tool because:
  - It's well known. Everyone is familiar and comfortable with an average.
  - There is only one for every quantitative data set.
  - It's easy to use to compare data sets. If there are two data sets of the same kind – for example, two data sets of flight times of aircraft – and the mean for one data set is 10.5 hours and for the second data set is 11.0 hours, then it is possible to assume the data sets group around approximately the same mean.

- Every item in the data set is taken into account.

- The main disadvantage to using the mean is that it can be affected by extreme measurements.

  - As an example of how the mean can be influenced by extreme data points, suppose you are asked to evaluate the salaries of a group of contractors working on a specific DoD project. Their salaries (in thousands of dollars) are as follows:

10.0	22.0	33.0	11.0	10.0	45.0	50.0	12.0	13.5	60.0
10.0	11.0	60.0	12.0	12.5	11.0	20.0	25.0	30.0	11.0

- The average of this data is the sum of the data elements divided by the total number of data points. That is, $469.0 divided by 20, or $23.45. This average implies that the salary paid to most of the contractors is around $23,000.00 In actuality, there are only three or four individuals who are making close to this salary. What has happened is that the higher contractor salaries (those in the forty to sixty thousand dollar range) have pulled the average up. Most of the *contractors make in the ten to eleven* thousand dollar range.

Mode

- The mode is a valuable tool because:

  - It is the easiest to find.
  - It can be used for both qualitative and quantitative data sets.
  - It is often more indicative of the actual central tendency of a data set than other measures.

- The disadvantage to using the mode is that some data sets do not have one and some have more than one. There may be two values in a data set that occur with the same frequency.

- As an example of one of the advantages of the mode, the data element that occurs most frequently in the data set above is $11,000.00. This figure is more indicative of the salaries being paid to the contractor staff than is the mean of the salaries.

Median

- Advantages of the median include the following:

  - Every quantitative data set has only one median.
  - The median is not strongly affected by extreme measurements.
  - It can be used with ordinal data.

- We can see an example of the median not being affected by extreme measurements by taking the median of our data set above. The reordered data set is:

10.0	10.0	10.0	11.0	11.0	11.0	11.0	12.0	12.0	12.5
13.5	20.0	22.0	25.0	30.0	33.0	45.0	50.0	60.0	60.0

- The rank of the median for this data is (n+1)/2 = (20+1)/2 = 10.5. Because this data set has an even number of data elements, the rank indicates that the median is located halfway between the tenth and eleventh number. The tenth number is 12.5; the eleventh is 13.5. Halfway between these two numbers is (12.5 + 13.5)/2 = 13.0. So the median for this data set is $13,000.00. You can see that the median has not been strongly affected by the higher salaries.

- There are also disadvantages to using the median.

  - Computing the median requires sequencing the data, which may be very difficult to do with large data sets.

  - It only uses one or two values from the data. Therefore, the data may be dramatically different but have the same median. For example:

    -- For the data set 1, 2, 3, 4, the median is 2.5.
    -- For the data set -50, 0, 2, 3, 75, 80, the median also is 2.5.

Choosing the Measure of Central Tendency

- *Which measure of central tendency should you use?* The best answer is to use all three if your purpose is to describe a set of data properly.

- Interesting things can be done with measures of central tendency to (mis)represent a group of data. For example, how would you interpret the following?

  "Half of the civilians working for the Department of Defense make salaries higher than the median salary level."

  OR

  "Most of the military installations in the Continental United States are rated average for their overall compliance with federal environmental standards."

EXERCISE 3-2

CALCULATING THE MEAN, MODE, AND MEDIAN

Exercise 3-2: Calculating the Mean, Mode, and Median

Task 1: The data below are the flight times in hours of 10 aircraft training flights. Calculate the mean, the mode, and the median.

5.916	4.155	5.271	5.390	4.502
5.182	4.489	5.995	4.208	4.219

If the data point 6.0 hours were added to the data set, how would you calculate the median?

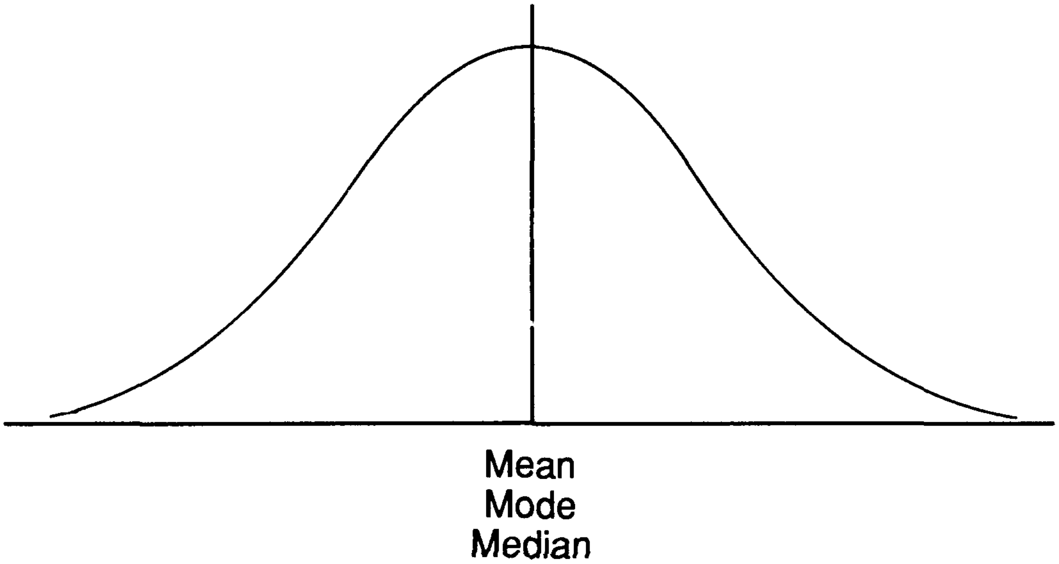
Discussion Question: Which measure of central tendency do you think best represents this data set?

Task 2: The data below are from a test of a man-portable missile guidance system and represent the number of seconds required before locking onto a test target. You are asked to give your best estimate of a representative time given this data set. How would you accomplish the task?

Guidance System Test Data

0.45	0.48	0.45	0.45	0.49	0.52
0.59	0.49	0.32	0.45	0.50	0.34
0.33	0.42	0.43	0.52	0.47	0.44
0.52	0.38	0.42	0.44	0.54	0.55

Normal Distribution



Statistical Theory and Tools

- The next subject to be covered is the normal distribution. The normal distribution is a curve, often called a bell curve, upon which many statistical analyses are based. The characteristics of the normal distribution include the following.
  - The mean, mode, and median of a normal distribution are all the same value.
  - The mean, mode, and median divide the distribution into two equal-sized, symmetrical parts.
  - The ends, or "tails," of the distribution get closer to the x-axis as they get farther from the mean, but they never touch the x-axis.
- The normal distribution is important to you for several reasons.
  - There are many instances in which data are normally distributed. For example, height, weight, and intelligence are normally distributed.

  - Studying and understanding the variation in a process is an important part of TQM, and the normal distribution helps in analyzing and understanding that variation.

- Notice that the mean of the normal distribution turns out to be nothing more than the type of mean you have calculated already. Since the mean, mode, and median are the same for the normal distribution, you need calculate only one value.

Measures of Variation

The Range

The range is equal to the largest value in the data set minus the smallest value in the data set.

Advantage:	Easy to calculate and understand
Disadvantage:	Does not reveal information about how values in between are dispersed

Statistical Theory and Tools

- Next we will discuss two measures of variation: the *range* and the *standard deviation.*
- The range of a data set is simply the difference between the largest and smallest data values.

  Range = largest value - smallest value = $X_L - X_S$

- For the data set 1, 7, 14, 14, 15, 22, 25, the range is 25 - 1 = 24.
- The aJvantage of using the range is that it is easy to calculate and easy to understand.

- The disadvantage of the range is that it only uses two values from the data set: the largest and the smallest. Therefore, the range doesn't tell you anything about how the data between these two values are dispersed. For example, in the data set 23, 24, 26, 26, 26, 33, the range is 10, but this number doesn't say anything about how the data are dispersed. You can see that the data are closely grouped around the value 26, the mode; however, the range does not indicate this grouping.

Measures of Variation

Standard Deviation

$$\sigma = \sqrt{\frac{\sum(x - \mu)^2}{n}}$$

x = value of a particular data point

$\mu = \dfrac{\sum x}{n}$ = mean (average) of data points

n = number of data points

Statistical Theory and Tools

- The second measure of variation we will cover is the *standard deviation.*
- The *standard deviation* measures the variability or spread of data. More precisely, it represents the extent to which the data points vary about the mean.
- The formula for the standard deviation is shown above. It may look complicated, but it really isn't. An example will show you how to use the formula.
  - Suppose we have the following data: 1, 5, 5, 6, 8, 11.
  - We begin by calculating the mean, μ, just as we did earlier.

$$\mu = (1 + 5 + 5 + 6 + 8 + 11)/6 = 6.$$

- Then, for each data point, we subtract the mean from the data point and square the difference (multiply the difference times itself). Next we sum all of the squared differences. These calculations are illustrated in the following table.

x	$(x-\mu)$	$(x-\mu)^2$
1	1 - 6 = -5	25
5	5 - 6 = -1	1
5	5 - 6 = -1	1
6	6 - 6 = 0	0
8	8 - 6 = 2	4
11	11 - 6 = 5	25

		$\Sigma = 56$

- Finally, we divide the sum of the squares by the number of data points and find the square root of the result. (The square root of a number is that value that can be multiplied by itself to equal the number. $\sqrt{}$ is the symbol for square roct.) In this example, the sum is 56 and the number of data points, n, is 6. So the standard deviation of this data set is the square root of 56 divided by 6.

$$\sigma = \sqrt{56/6} = 3.055$$

- It should be noted that it is better not to round any of the components of the standard deviation; wait to round until you have the final figure.

- Many calculators have easy-to-use mean and standard deviation functions. In addition, many computer applications can do most of these calculations. All you have to do is input the data.

- The above example uses a small number of data points for instructional purposes only. Normally, data sets with fewer than 30 data points require a special formula for calculating the standard deviation. This formula is discussed on the next page.

Measures of Variation

Standard Deviation of Small Sample Sizes ($n \leq 30$)

$$s = \sqrt{\frac{\sum (x - \mu)^2}{n - 1}}$$

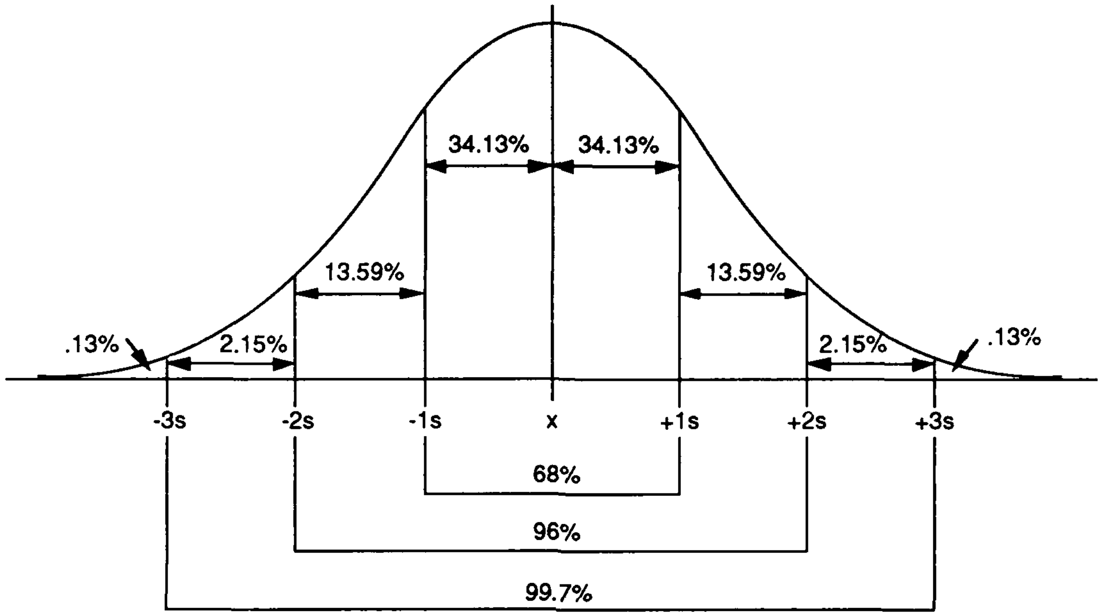
Statistical Theory and Tools

- Shown above is the formula for the standard deviation of data sets containing less than 30 data points. It is slightly different from the one on the previous page; the only difference is that you divide by (n -1) instead of n.

- Whenever we obtain a set of data, by doing a test or by measuring something, it is only a sample of the real population. This means that if we were measuring tire wear of a particular brand of tire, the real world or real population would be measured only if we examined every one of the tires of this brand ever made. The value of statistics is that we can randomly select a sample of data from the population. For instance, we can select only 25 tires and use statistical methods to estimate what the mean and standard deviation of the population is.

- The formula for the standard deviation of small sample sizes is used to account for the increased possibility that the real population mean is a different value than the sample mean.

Normal Distribution & the Standard Deviation



Statistical Theory and Tools

- The standard deviation has some definite advantages.
  - It takes into account all the data in the data set and is easy to interpret.
  - It can be used to determine what proportion of a given set of data will fall above or below a value.
- The chart above shows the normal distribution with one, two, and three standard deviations marked on it. The general rule is that:
  - 68% of the measurements fall within +/- 1 standard deviation from the mean.
  - 96% of the measurements fall within +/- 2 standard deviations from the mean.
  - 99.7% of the measurements fall within +/- 3 standard deviations from the mean.

- To put three standard deviations in perspective, assume that the average number of words on a printed book page is 530. The following accuracy can be expected if quality is maintained at the indicated standard deviation (σ) level.

1 σ accuracy	170 misspelled words per page
2 σ accuracy	25 misspelled words per page
3 σ accuracy	1.5 misspelled words per page
4 σ accuracy	1 misspelled word in 30 pages
5 σ accuracy	1 misspelled word in a set of encyclopedias
6 σ accuracy	1 misspelled word in all the books in a small library

* The Nature of Six Sigma Quality, Mike J. Harry, Motorola Inc., Government Electronics Group.

- The standard deviation has only two disadvantages: it can be tedious to calculate, and it can be used with quantitative data only.

- Using a calculator with a statistical function or a computer with a statistical package can overcome the first disadvantage.

Exercise 3-3

CALCULATING THE STANDARD DEVIATION

Exercise 3-3: Calculating the Standard Deviation

Scenario: The data below represent a random sample of the time (in hours) it takes to unload a particular type of Navy tender.

36	36	37	37
41	41	42	43
45	45	46	46

Task: Calculate the range and mean of the data set. Then calculate the standard deviation using the formula for small sample sizes.

Sampling

What Is Sampling?	Selection of representative elements from a target population to gain information about the entire target population
Why Use Sampling?	• Target population too large • Target population geographically separated • Save time and money

Statistical Theory and Tools

- In the Do phase of the PDCA cycle, you must determine specifically how you will collect your data. For most situations, sampling can give you good insight into the target population, without the difficult task of collecting data from the total target population.

- The benefits of sampling are indicated above. It is rarely necessary or possible to gather data on the whole target population. If the sampling is properly done, it will be representative of the target population, and results obtained from analyzing sample data will be relevant to the target population.

- Sampling also saves time and money. For example, suppose that you are participating on a process action team tasked to make improvements in the coordination process. The team decides to gather data using interviews. The interview design involves 17 questions and requires approximately 15 minutes to administer. Because there are approximately 5000 personnel in OSD (the target population), it would take a minimum of 1,250 hours to get the job done, not counting the administrative time necessary to compile the results. If a 10% sample were used, only 125 hours would be required. The critical question that

needs to be answered concerns the validity of the results obtained by sampling "only" 10%: To what extent will the sample represent the target population?

Sampling

Sampling Procedure

Identify the Target Population

↓

Determine the Sample Size

↓

Select the Sample

Statistical Theory and Tools

- The first step in the sampling process is to identify the target population. Identifying the target population is not as easy as it might appear to be because the characteristics of the target population have to be clearly defined.

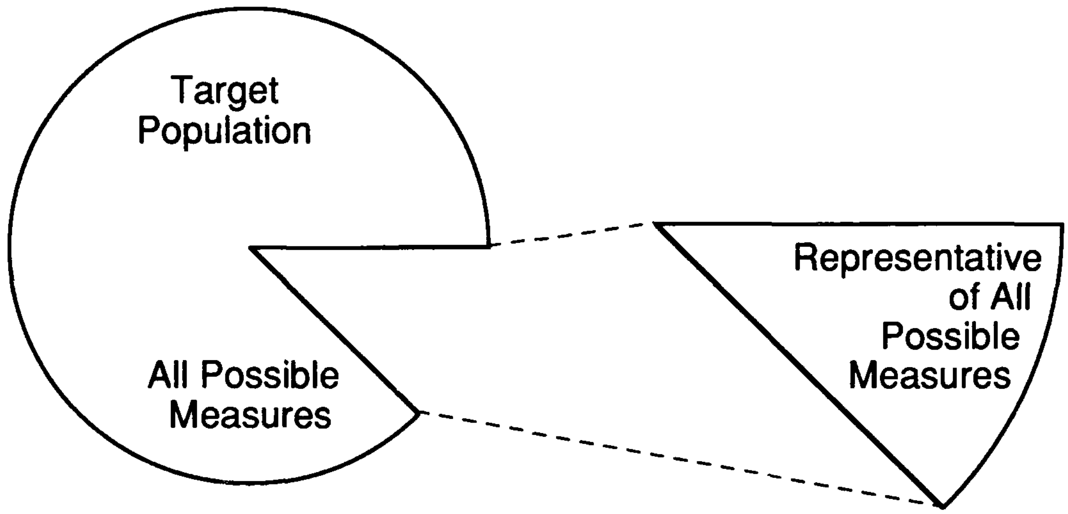
- For example, suppose you wanted to sample the OSD staff to collect data on the number of staff hours being devoted to the budget estimate submission (BES). You might consider the target population to be all the personnel who work for the comptroller. But that would assume that all the comptroller staff work on the BES, and it would also assume that no other OSD staff work on the BES. Because neither of these assumptions is correct, any sample developed from this target population would be biased – not reflective of the true population of OSD staff who work on the budget submission.

- One of the most frequent errors in defining a target population has to do with assuming that nominal population classifications are homogeneous in their characteristics. Take for example a cohort population of military personnel eligible to separate from the service in a given time period. Suppose sample data are collected from those who decide to separate. This kind of sampling is

usually done to gather data on reasons why personnel separate and to act on this information to improve retention. However, such an approach assumes that all personnel eligible to separate are a homogeneous group. Reasons given for separating are significant to all members of this cohort group, even though only the personnel separating are identified as the target population from which the sample is drawn. Information gathered from this kind of sampling may be interesting, but would not be representative. Therefore, it should not be used to guide decision making on the subject of retention.

Sampling

Sample Size



Statistical Theory and Tools

- There are guidelines for determining sample size. In general, the size of the sample needed depends on the type of research being done. For initial descriptive research in a problem area, a 10% sample size is adequate. However, if the target population is in the hundreds, the sample size should be higher, approximately 20%.

- If the purpose of taking the sample is to make determinations about rare or unique conditions in the population, then a large sample is needed. For example, if you were trying to sample OSD personnel to determine how many had certain unique analytical skills, the sample size would have to be large to ensure that personnel with the unique skill would have a good chance of being included in the sample. The terms large and small are defined in relation to the target population. If the target population is 10,000, then a sample of 100 is 1% and would be considered small (not necessarily inadequate). If the target population is 500, then a sample of 100 is 20% and would be considered large (not necessarily adequate).

- In sampling, precision is not linearly related to the size of the sample. For example, a sample size of 50 is not twice as precise as a sample size of 25. To double the reliability of a sample size of 25, the sample would have to be increased to 100. Also, while larger samples are generally better than smaller ones, large samples also can lead to erroneous conclusions because sampling bias can affect a study regardless of sample size.

- This brief discussion on sample size is designed to provide you with an introduction to the subject. Statistical techniques can be used to estimate required sample sizes for different types of studies. The assistance of a trained researcher may be needed to apply these techniques.

- To conclude the discussion of sampling size, the principal thing to keep in mind is that while the size of the sample is important in research, it is not the most important thing. The method of selecting the sample to avoid bias is the most important parameter.

Sampling

Sampling Techniques

- **Random Sample**
- **Stratified Sample**
- **Cluster Sample**

Statistical Theory and Tools

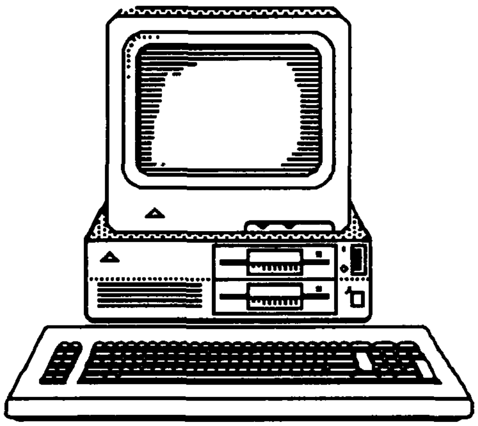
- There are three basic sampling techniques used in research. Each is described in the following pages.

Sampling

Random Sampling

Random Numbers Table	
54463	96754
15389	34357
85941	06318
61149	62111
05219	47534
41417	98614
28357	24856
17783	24856
177783	96887
40950	90801
82995	55165

Computer Generated



Statistical Theory and Tools

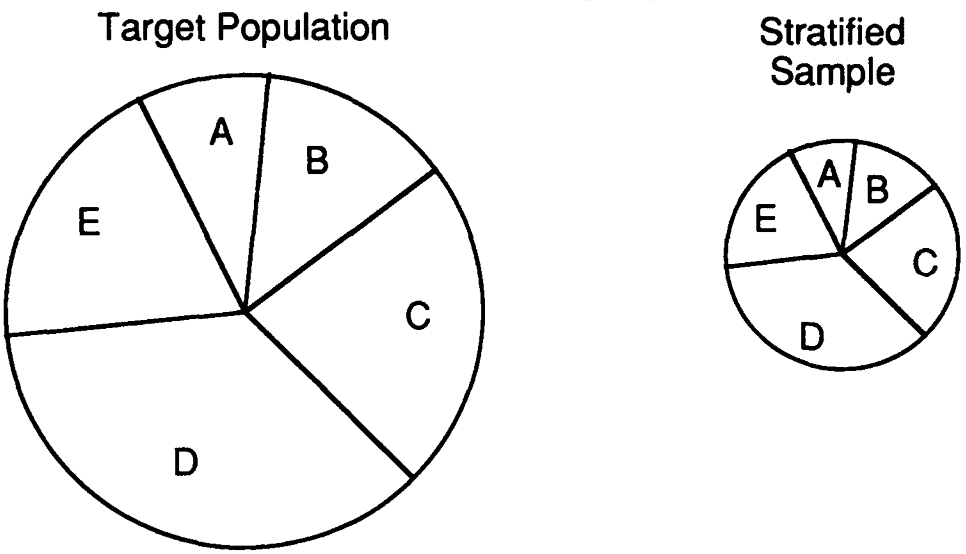
- The random sample is just what its name implies. It is a sample that is selected in such a way as to ensure that every one of the items that make up the target population (people, things, events) has an equal and independent chance of being selected as part of the sample.

- Random sampling is the best way to obtain a representative sample of a homogeneous population. Properly employed, it ensures that no bias is introduced *by personnel gathering the data.* Random sampling is still subject to bias; however, such bias would be *a function of chance.*

- Random sampling can be accomplished by using a random numbers table, which can be found in any introductory book on statistics. Additionally, many computer programs for microcomputers can generate random numbers or mix data based on random numbers.

Sampling

Stratified Sampling



Statistical Theory and Tools

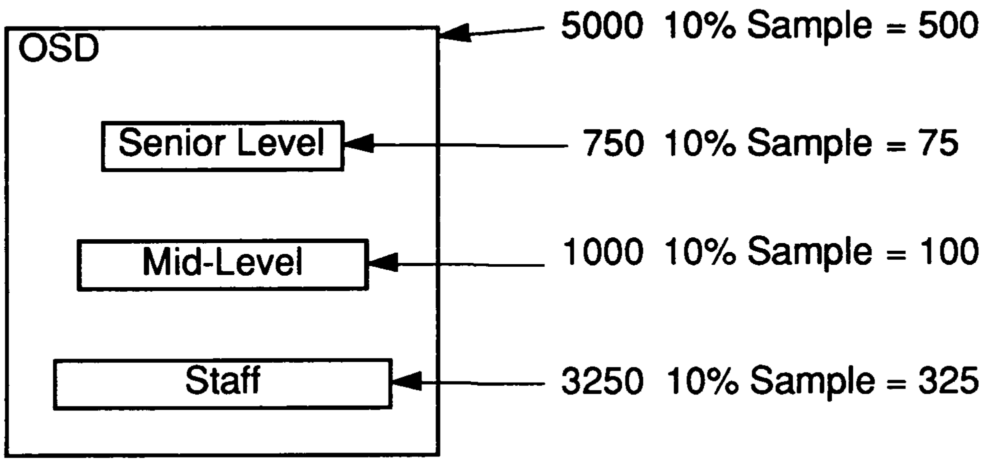
- Stratified sampling selects a sample to ensure that subgroups in a target population are represented in the sample in the same proportion that they exist in the target population. For example, if one wanted to sample correspondence distribution effectiveness in OSD, a simple random sample would not ensure that a good representation of all the different levels in the organizational structure was achieved. Therefore, it would be more appropriate to stratify the sample to ensure that the different organizational levels would be proportionally represented.

- Stratification can be done in different ways for the same target population. For example, a stratified sample of a division could be based on different office functions. The same division also could be sampled based on job skills, and the sample elements would be totally different. The parameter used for stratification is determined by the nature of the research.

- Stratified sampling also requires steps to ensure randomness in selecting samples in the different categories of stratification.

Sampling

Stratifed Sampling



Statistical Theory and Tools

- Consider an example of a stratified sample in OSD. Suppose a representative sample of OSD personnel was needed to do a survey on attitudes about TQM. There are approximately 5,000 personnel assigned to OSD (not counting mission support personnel). If a sample size of 10% were used, 500 test subjects would be needed.

- In this example, OSD is organized into three basic personnel subgroups: senior level (15% of population), mid-level (20% of population), and staff personnel (65% of population).

- To obtain a 10% stratified sample, a computer listing of all DoD personnel is segmented into the above subgroups, each subgroup listing is mixed using computer random number generation, and 10% of the names are selected.

- The resulting list of names would be a good representation of the organization and would also represent a randomly drawn, stratified sample.

Sampling

Cluster Sampling

- Groups are selected at random.
- All group members/test items are used.

Statistical Theory and Tools

- Cluster sampling is an economical method for collecting data when the target population is spread out geographically. It is an appropriate method for the DoD, where similar units are spread out all over the world, and it is not feasible to use a simple random sample or stratified sample.
- Two examples of clusters are similar types of units and similar equipment in units. In both examples, it would be easier and more economical to take a survey of all the personnel in one unit than to spread the requirement out over several units. The same is true for sampling equipment readiness.
- The TQM survey of OSD personnel used as an example for stratified sampling also could have been accomplished using the clustering technique. Offices with similar functions could have been selected randomly, and all the personnel in the functional unit could have been surveyed.
- Using cluster sampling has two main disadvantages. The first, and primary, disadvantage is that clustering can introduce a great deal of bias. In the example of taking a survey about TQM attitudes, suppose one of the units selected was a

TQM office – the resulting data probably would be biased in favor of TQM. The second disadvantage is that cluster sampling data can only be treated in a limited way statistically because this method does not really generate random data.

- Cluster sampling is a good "first look" data gathering method. If care is used in defining the clusters, the data will be representative enough to guide further action.

MODULE FOUR

PLANNING AND DOING:

FLOW CHARTING AND CAUSE AND EFFECT DIAGRAMMING

Module Four Objectives

Upon completion of this module, participants will be able to:

- Describe the technique of flow charting a process.
- Apply flow charting to a DoD process.
- Describe the technique of cause and effect diagramming.
- Apply cause and effect diagramming to a DoD process.

Planning and Doing: Flow Charting & Cause and Effect Diagramming

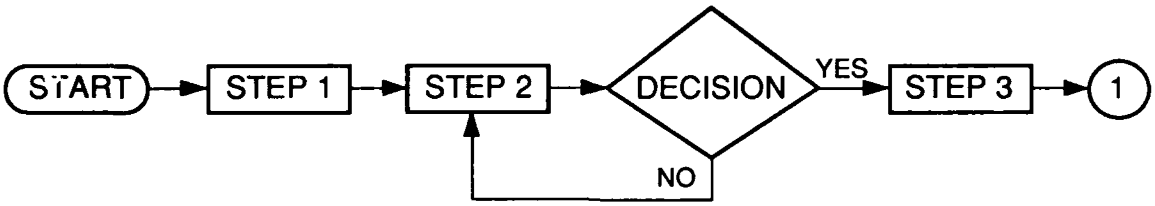
What is a Flow Chart?

FLOW CHART:

A diagram of the steps in a process and their interrelationships.

- A useful flow chart must illustrate steps in a process rather than the organizational hierarchy of the personnel involved in the process. A flow chart focusing on the steps provides a cross-functional view of the process which is very useful when you analyze the interrelationships between process steps and attempt to identify process improvement areas. Many people fall into the trap of flow charting the structure of their organization. An effective way to avoid this problem is to *include an action verb and a noun (object) in each step box of your flow chart.* Following this rule will remind you to capture the actions of your process, what really happens, rather than the organizational flow of who gets what after whom.

What is a Flow Chart?



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- A flow chart consists of a few geometric symbols (rectangles, diamonds, etc.) connected by arrows that indicate the direction of flow of the process.

- A symbol may represent:

  - The beginning or end of the process
  - A process step
  - A decision point
  - A reference to a subprocess or continuation of the process
  - Any aspect of the process (for example, inspection or transportation).

- Flow charts usually are used during the Plan phase of the PDCA cycle. They help establish baselines of how work currently is accomplished.

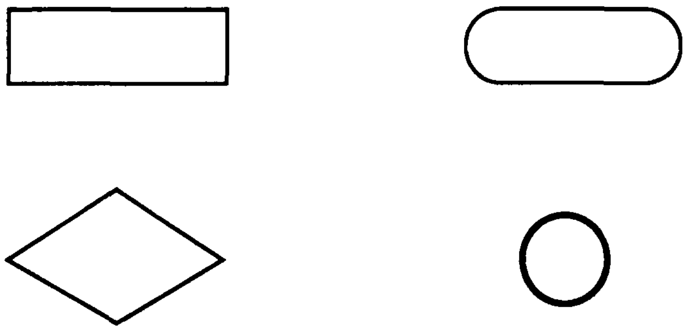
Benefits of Flow Charting

- **A flow chart can help you:**
  - Determine the steps in a process and better understand their interrelationships.
  - Identify unnecessary steps or inefficiencies.
  - Identify the differences between how a process should work and how it does work.
  - Target specific areas for process improvement.

- It is beneficial to flow chart all processes -- even those that appear to work well.
  - Most processes can be improved and flow charting can help point out any inefficiencies.
  - Remember: TQM stresses continuous process improvement.

Creating a Flow Chart

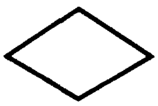
- **Flow charts do not need to be complicated.**
- **As few as four symbols can be used to create a good flow chart:**



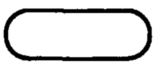
Planning and Doing: Flow Charting & Cause and Effect Diagramming

- The following four symbols are the basic symbols needed to create a flow chart:

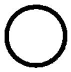
Activity Symbol: Indicates one activity, or step, in the process.



Decision Symbol: Indicates a point at which the process branches. The decision symbol should not be used to represent a decision process, only a decision point. A decision process should be represented by an activity symbol, and then a decision symbol to route the process based on the outcome of the decision.

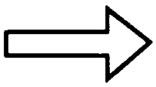


Terminal Symbol: Identifies the first or last step in a process. Usually contains the words "start" or "stop," or "begin" or "end."

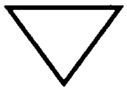


Connector: Indicates that the process continues elsewhere. You can use this symbol to continue a process on another page or to reference a subprocess diagrammed on another chart.

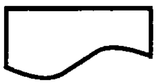
- Other symbols that may be used include:



Transportation Symbol



Storage Symbol

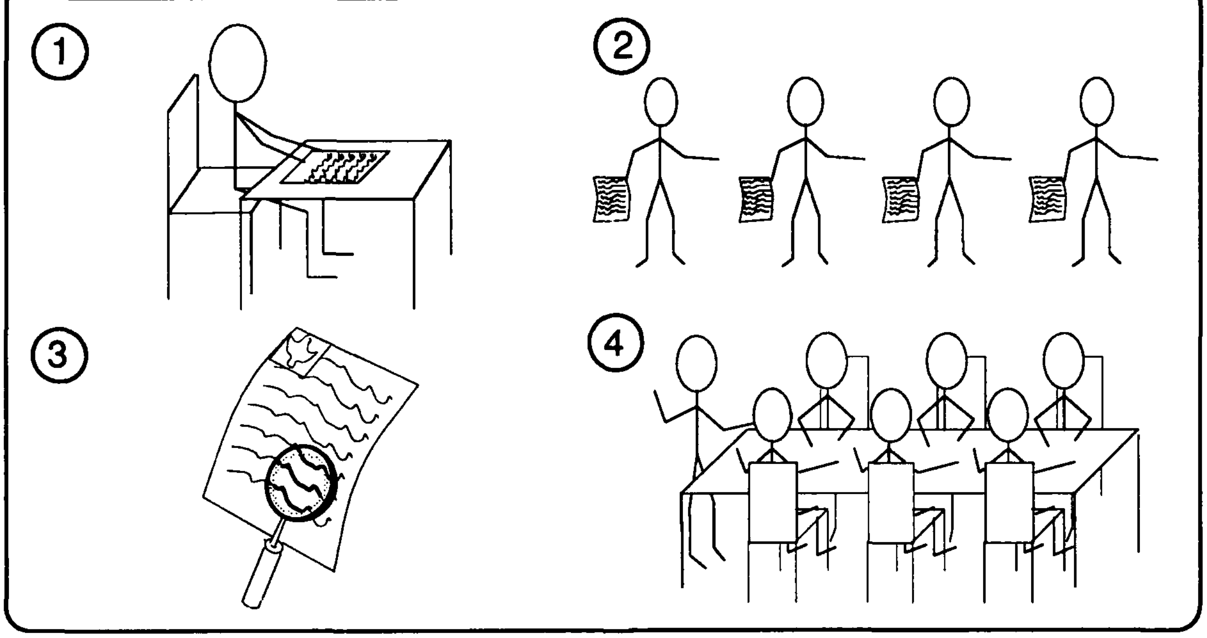


Document Symbol

R Rework Symbol

D Delay Symbol.reference a subprocess diagrammed on another chart.

Applying Flow Charting



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Use four basic steps to apply flow charting in your organization:

  1. Flow chart the process yourself, only if you understand the process well.

  2. Get independent feedback from others who understand the process. This feedback provides different perspectives of the process.

  3. Determine how directions and regulations impact the process.

  4. Conduct a meeting to develop a comprehensive flow chart from the input of all process participants.

Creating a Flow Chart

Process Flow Worksheet

#	Step Description	Symbol	#	Step Description	Symbol

Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Do not begin charting a process flow by drawing the flow chart.
  - Processes are often more complex than anticipated and beginning with the flow chart can be messy and frustrating.
  - Listing the steps of the process first makes flow charting easier.
- Begin creating your flow chart by using a process flow worksheet like the one shown above.
  - Write down the steps in the process <u>in the order in which you think of them</u>.
  - After listing all steps, assign a sequence number to each. Write these numbers in the left column of the worksheet.
  - Then, using the right column, assign a flow charting symbol to each step.
- After completing the process flow worksheet, sketch the flow chart.

Exercise 4-1

Flow Charting a Process

Exercise 4-1: Flow Charting a Process

Scenario: Your office has a drip coffee maker. Recently, people have been complaining about the taste of the coffee.

Task: Individually, generate a list of steps for making good coffee, using the form below. Then, as a group, flow chart the process of making coffee to help determine what is making the coffee taste bad. (Keep in mind that this problem addresses the taste of the coffee.)

#	Step Description	Symbol

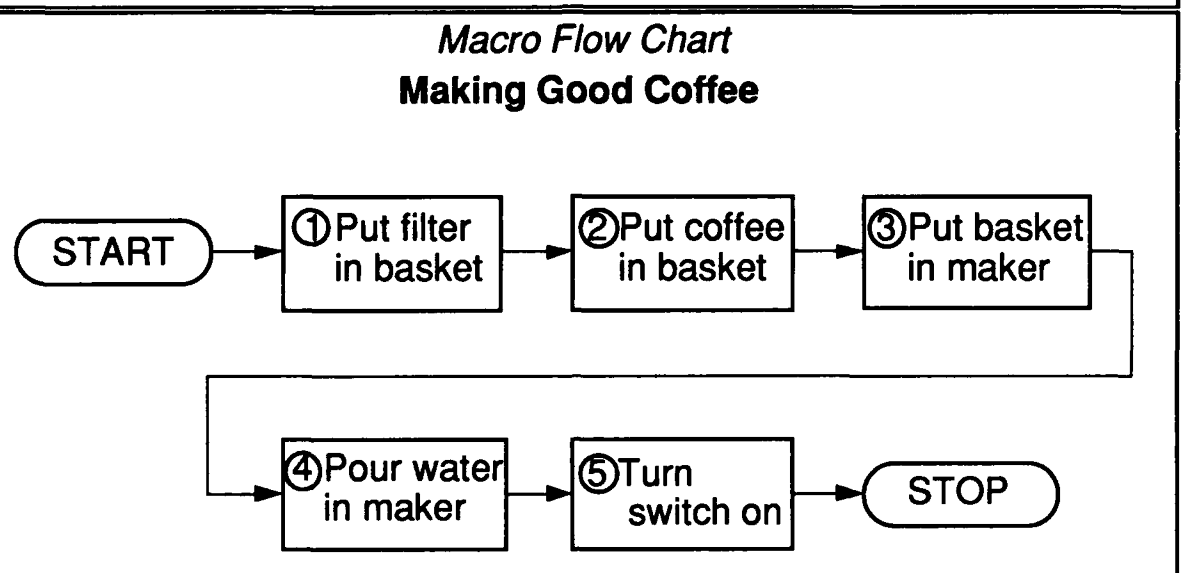
Exercise 4-1: Flow Charting a Process

Discussion Questions:

1. What are the benefits of listing the steps in a process before drawing the flow chart?

2. What are the benefits of getting input from others familar with the process?

Applying Flow Charting



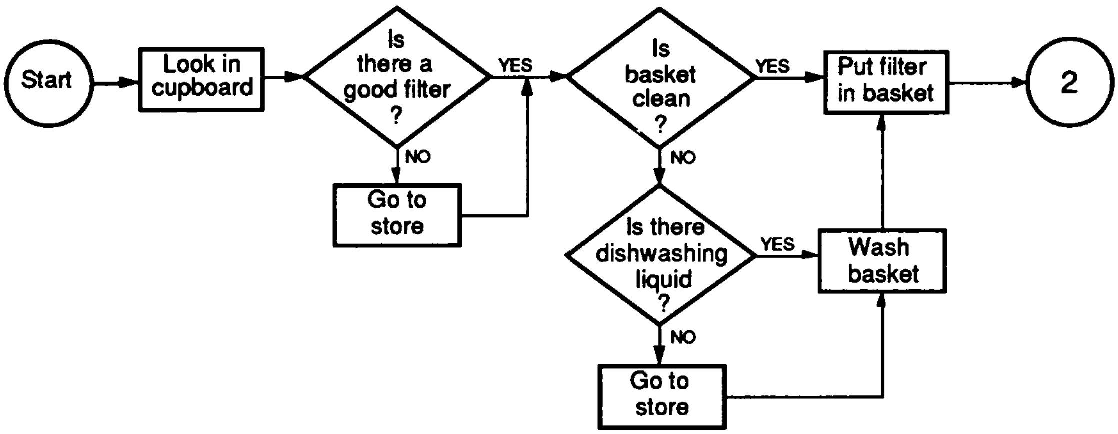
Planning and Doing: Flow Charting & Cause and Effect Diagramming

- It often is beneficial to begin the flow charting process by charting the major, or high-level, steps in a process. This type of flow chart is called a *macro flow chart.*
  - Macro flow charts help you determine and sequence the high-level steps in a process without becoming immediately involved in the detailed procedures.
  - Macro flow charts also help simplify each chart, making them easier to follow.
- Charts of more detailed, or low-level, procedures in a process are called *micro flow charts.*

Applying Flow Charting

Micro Flow Chart

Step 1: Put Filter in Basket



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Each major step in the macro flow chart should be represented in a micro flow chart.
- A highly complex task may have more than one layer of micro flow charts.
- The example above shows a micro flow chart for Step 1, Put filter in basket, in the macro flow chart.

Exercise 4-2

Flow Charting a DoD Process

Exercise 4-2: Flow Charting a DoD Process

Task 1: Think about how incoming phone calls are handled in your office. Using the form below, list the major steps currently used to handle incoming calls. Then sequence the steps and assign a flow charting symbol to each. Finish by drawing a macro flow chart of the process.

#	Step Description	Symbol

Macro Flow Chart

Exercise 4-2: Flow Charting a DoD Process

Task 2: Compare the macro flow charts of all the group members. Then consolidate them into one macro flow chart of how incoming phone calls should be handled. Next choose the macro step that the group feels is most problematic and create a micro chart for that step. Concentrate on how incoming calls should be handled.

#	Step Description	Symbol

Exercise 4-2: Flow Charting a DoD Process

Micro Flow Chart

Exercise 4-2: Flow Charting a DoD Process

Discussion Questions:

1. How did the macro flow charts showing how incoming calls <u>are</u> handled differ from those showing how calls <u>should be</u> handled?

2. Based on this exercise, which parts of the call-handling process would you target for improvement?

3. Which area would you try to change first?

4. How did you decide which area to target first?

Applying Flow Charting

Final Points and Reminders

- Computer programs are very useful for flow charting.
- It is beneficial to flow chart processes that appear to be working well.
- Flow charts help eliminate the perception that processes are working as they should.
- Flow charts are an excellent tool for pointing out nonproductive work.

Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Various computer programs are available for flow charting.
- Flow charting can point out inefficiencies in processes that appear to be working well.
  - The philosophy of "If it ain't broke, don't fix it" is not compatible with TQM.
  - Continuous improvement is crucial to successful TQM.
- Processes evolve over time, often by informal means. Flow charts can establish a baseline of how processes really work.
- Flow charting assists people in thinking and communicating about processes, a key to the TQM focus on processes.
- Flow charting is useful in defining the process, so everyone involved has a common understanding of how the process functions.

What is a Cause and Effect Diagram?

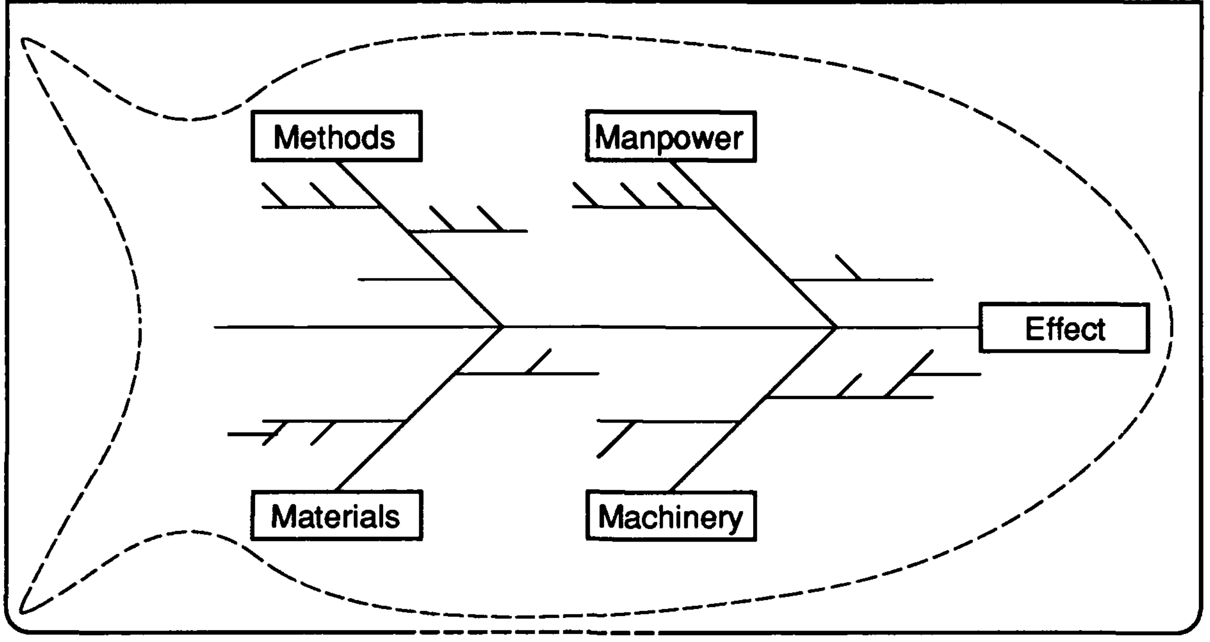
CAUSE AND EFFECT DIAGRAM:

A graphic representation of the relationships between some "effect" and the possible causes of that "effect."

Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Another tool used in process analysis is the *cause and effect diagram.*
- The cause and effect diagram is used to nominate possible causes for some "effect" or problem in a process.
- The cause and effect diagram also illustrates the relationships between the possible causes and the effect.
- The *effect statement* (description of the effect being studied) should be an unambiguous, unsuggestive description of a problem or situation.

What is a Cause and Effect Diagram?



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- The cause and effect diagram sometimes is called a fishbone diagram because its branching pattern resembles the skeleton of a fish. It also is known as an Ishikawa diagram, after Kaoru Ishikawa, a quality authority who pioneered its use in identifying causes of work process variation.

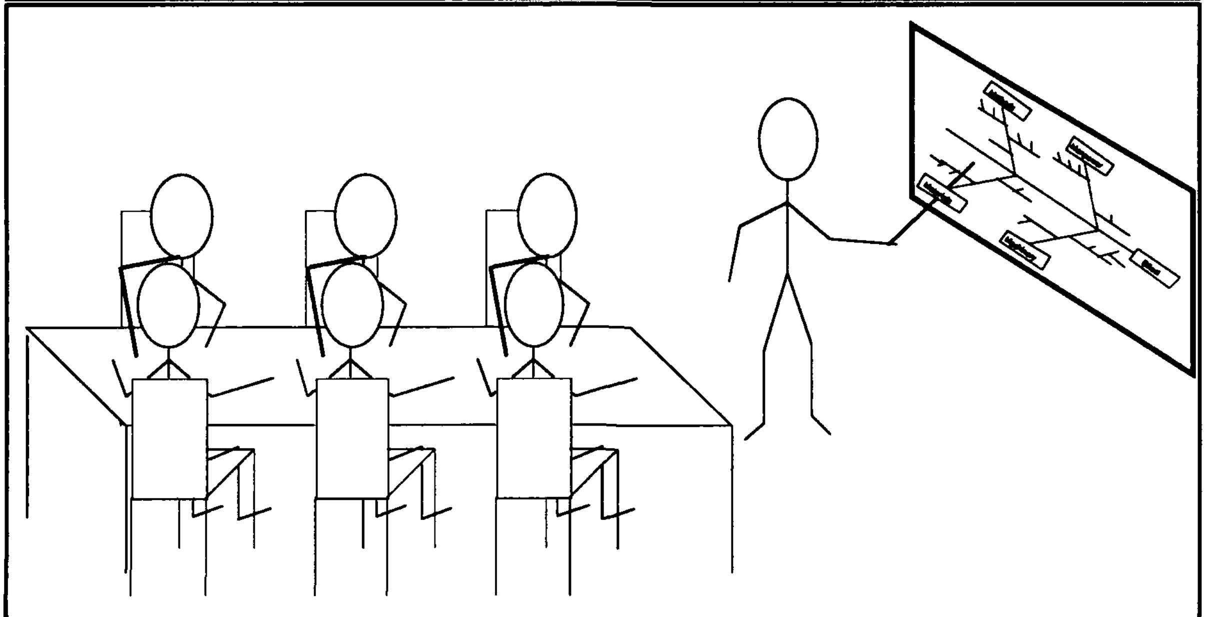
- By illustrating the relationships between some problem or effect and its possible causes, the cause and effect diagram aids in:

  - Analyzing complex interactions
  - Identifying specific potential causes of a problem
  - Generating potential solutions to a problem.

- Methods, Manpower, Material, and Machinery -- or the four Ms -- are major categories of possible causes often used in a cause and effect diagram. Any category may be used, however. Four categories often used in administrative areas are Policies, Procedures, People, and Plant -- the four Ps.[1]

[1] G.O.A.L., The Memory Jogger: A Pocket Guide of Tools for Continuous Improvement, (Lawrence, MA: G.O.A.L., 1985), p. 21.

Applying Cause and Effect Diagramming



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Cause and effect diagramming is combined with brainstorming to:

  - Generate a large number of potential causes
  - Encourage cooperation among people involved with a process
  - Utilize the knowledge of <u>all</u> people involved with a process
  - Focus attention on a specific problem
  - Structure discussion to stimulate thinking and encourage creativity
  - Increase knowledge of a process.

- Among commonly used brainstorming techniques are the following.

  - <u>Modified Delphi Method</u>. In this method, each member of the group lists, by category, causes for the identified problem and submits his list to the group leader or facilitator. The group leader redistributes the lists so that group members are exposed to the ideas of others. Each member submits another list based on his reaction to the list of his peer. The group leader redistributes

the lists several more times and collects all of the lists. He then creates a cause and effect diagram from the group input and calls a meeting to discuss and finalize the diagram.

- Nominal Group Technique (NGT). The NGT is a five-step process for generating ideas and reaching consensus. When used with cause and effect diagramming, the five steps are as follows.

  1. Each member of the group lists, by category, potential causes for the identified problem.

  2. Each member in turn reads one idea from his list while the group leader or facilitator writes the idea on a flip chart. Group members take turns reading ideas until all ideas have been posted on the flip chart.

  3. Group members collectively review the combined list for omissions, overlap, and need for clarification.

  4. The group leader distributes to each member from five to nine "voting cards." The number of cards distributed depends on the number of ideas generated by the group. On these cards the group members write the ideas that they feel are most important and rank the selected ideas by order of priority.

  5. The leader prepares the cause and effect diagram based on the results of the voting, and the group discusses the diagram and potential next steps.[2]

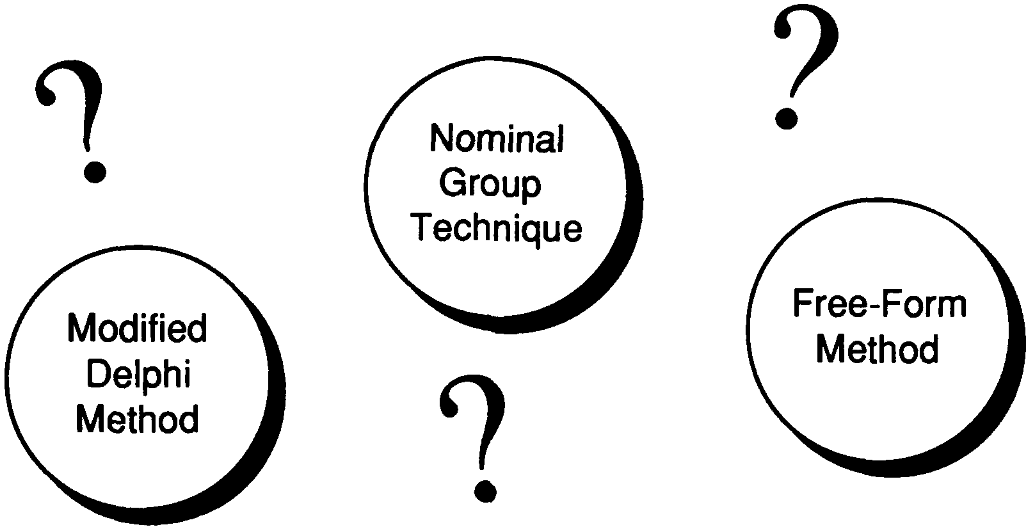
- Free-form Method. This brainstorming technique involves an open flow of ideas and stresses spontaneity and volume of ideas. No order is imposed on idea generation. Group members offer ideas as they think of them, and the leader writes each idea on the cause and effect diagram when it is suggested. Validity of ideas is not discussed during this session; members are encouraged to voice any idea, no matter how absurd it may seem.

• Other methods for collecting input to a cause and effect diagram also are used. One example is asking team members to observe the process between meetings and use check sheets to identify potential causes of the identified problem. (Check sheets are discussed in detail in Module V.)

[2] Scott Sink, "Using the Nominal Group Technique Effectively," National Productivity Review, Spring 1983, pp. 173-176.

Applying Cause and Effect Diagramming

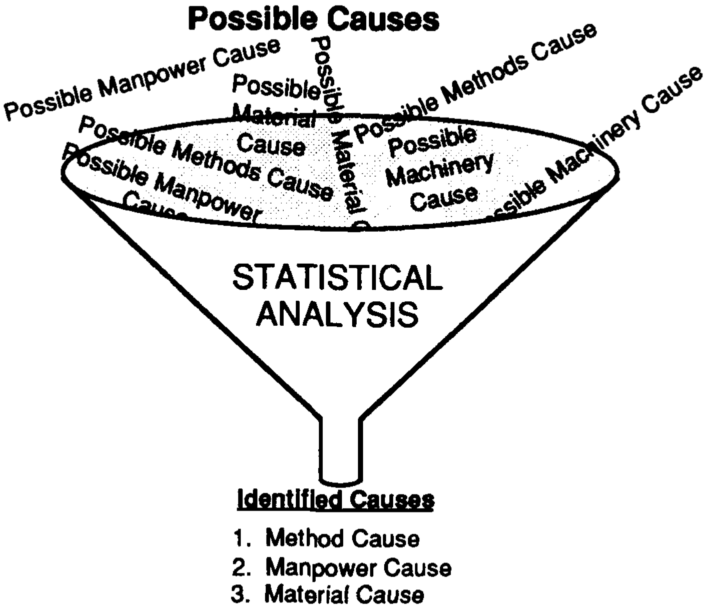
Brainstorming Techniques



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- The better brainstorming technique for cause and effect diagramming is the free-form method; however, group maturity determines which technique to use. Many factors may inhibit the success of a brainstorming session.
  - Members of recently formed groups often are not comfortable with sharing "creative" ideas.
  - A dominant group member may inhibit others.
  - Timid group members may not offer ideas.
  - Argumentative members may disrupt the generation of ideas.
- The group leader or facilitator must evaluate the group and determine its maturity. Only mature groups should use the free-form method.

Applying Cause and Effect Diagramming



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- It is important to understand that cause and effect diagramming generates only possible causes for an effect. An idea offered by a group member is a nomination for a potential cause that may be chosen for further study.
  - As a group, determine the high-priority possible causes that will be analyzed statistically. To determine which causes to study further, look for ones repeatedly suggested.
  - When the high-priority possible causes have been identified, prepare a plan for gathering data to determine frequencies, duration, and cost.
  - After gathering data, use analysis tools such as Pareto charts, histograms, and scatter diagrams to determine the area most in need of process improvement. (These tools will be explained later in the course.)

Exercise 4-3

Creating a Cause and Effect Diagram

Exercise 4-3: Creating a Cause and Effect Diagram

Scenario: Recently, people in your office have been complaining about the flavor of the coffee. The coffee drinkers in the office have gathered to discuss the possible reasons for the coffee's bad flavor.

Task: Using the free-form brainstorming technique, create a cause and effect diagram for the effect of bad-tasting coffee.

Discussion Questions:

1. How effective was the free-form method in generating potential casues of the problem?

2. What pattern, if any, did the generation of ideas take?

3. Did you learn anything new about the process of making coffee?

4. Did you solve the problem of bad-tasting coffee?

5. Will this exercise change your future thinking about how to make "good-tasting" coffee?

Exercise 4-4

Applying Cause and Effect Diagramming to a DoD Process

Ex. 4-4: Applying Cause and Effect Diagramming to a DoD Process

Scenario: Your office receives a large number of incoming phone calls. Staff have been complaining that these phone calls require a lot of time and disrupt other work. In addition, customers have been complaining that they have trouble reaching staff on the telephone.

Task: As a group, write an effect statement for this two-fold problem concerning incoming phone calls. Then create a cause and effect diagram to identify possible causes of the problem.

Discussion Questions:

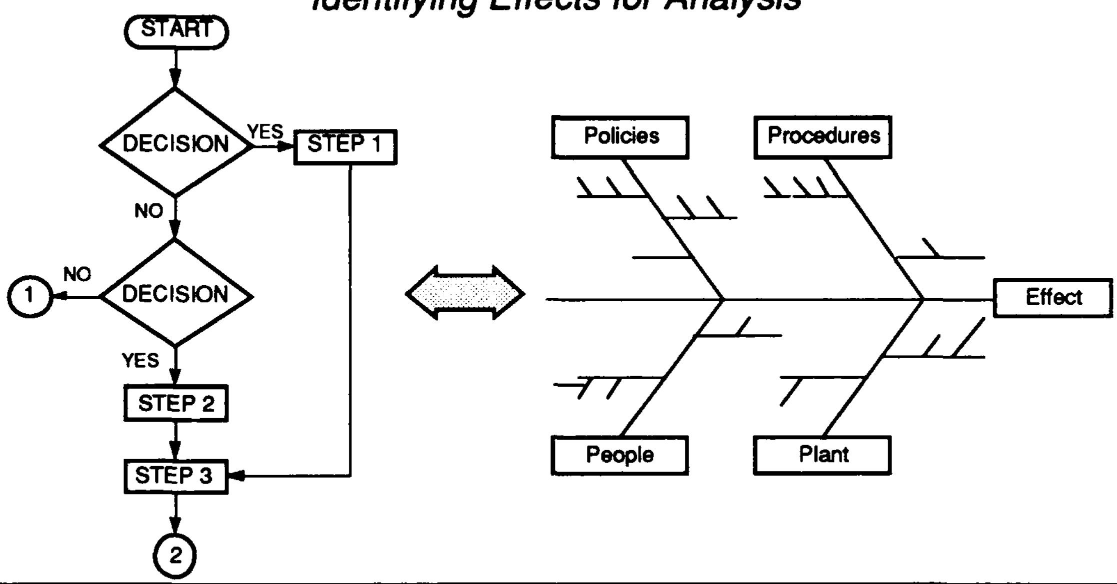
1. How do you think the wording of the effect statement affected idea generation?

2. What major causes did you identify in this exercise?

3. What steps would you take next?

Applying Cause and Effect Diagramming

Identifying Effects for Analysis



Planning and Doing: Flow Charting & Cause and Effect Diagramming

- Flow charts can be used to identify effects to be analyzed through cause and effect diagramming. Examine the flow chart for complex looping arrangements, dead ends, and other indications of process inefficiencies. Then conduct a cause and effect diagramming session for each identified effect.

- After cause and effect diagramming, compare the diagram with the process flow chart to identify potential areas for process improvement.

Applying Cause and Effect Diagramming

Final Points and Reminders

- **An effect statement should be an unambiguous, unsuggestive description of a problem or situation.**
- **Cause and effect diagramming generates potential causes of an effect.**
- **Potential causes must be analyzed statistically to identify real causes.**

MODULE FIVE

CHECKING AND ACTING:

CHECK SHEETS, PARETO CHARTS, HISTOGRAMS, AND SCATTER DIAGRAMS

Module Five Objectives

Upon completion of this module, the participant will be able to:

- Construct and apply check sheet methodology to record and process data.
- Explain the design concept of a Pareto chart.
- Display DoD type data in a Pareto chart and interpret the results.
- Explain the design concept of a histogram.
- Compare and contrast Pareto charts and histograms.
- Display DoD type data in a histogram and interpret the results.
- Describe the design concept of a scatter diagram.
- Display DoD type data in a scatter diagram and interpret the results.
- Explain how check sheets, Pareto charts, histograms, and scatter diagrams are used in the Check step of the PDCA cycle.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

CHECK SHEETS

Check Sheets

Problem	Week				
	1	2	3	4	Total
A	IIII	II	III	IIII	13
B	~~IIII~~	II	III	~~IIII~~	15
C	I	II	I	I	5
D	II	I	I	IIII	8
Total	12	7	8	14	41

Check Sheet: Simple form that supplies factual data about how often certain events happen.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Check sheets are a simple and effective way to collect the data needed for process analysis.
- Check sheets often are the starting point of a problem solving effort. The data collected from check sheets provide the baseline for effective process analysis.
- Check sheet data provide concrete facts from which we can look for trends and discover patterns that will allow us to improve the process. Without these facts, we must rely on opinions and subjective personal impressions about how often things happen and how important they are.
- The effectiveness of a check sheet often is determined before the form itself is even designed. The check sheet will be a valuable tool only if Process Action Teams can determine exactly what they want to measure.

A DoD Example

Problem: Rejections of policy statements

Reasons for Rejections:

- Lack of supporting data
- Faulty logic; didn't reason from cause to effect
- Inappropriate terminology; too technical
- Inconsistent with aspects of existing policy
- Mechanical problems – spelling, format, grammar

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The scenario above represents a fictional problem typical of those that top OSD managers face – the production of unacceptable policy statements by their staff.
- At a group brainstorming session using cause and effect diagramming, the Process Action Team discussed why managers reject policy statements. During the discussion, the PAT identified the five problems listed above as the major reasons for rejection.
- The PAT decided to develop a check sheet to determine how often each of these problems occurs.

A DoD Example

Reasons for Policy Statement Rejection

Deficiency	February			
	week 1	week 2	week 3	week 4
Lack of Supporting Data				
Faulty Logic				
Inappropriate Terminology				
Inconsistent with Existing Policy				
Mechanical Problems				

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The above check sheet represents a form that can be used to track data on unacceptable policy statements. The form is very simple and is easy to use and understand; yet it allows PATs to effectively capture the necessary data.

- To use the form, the manager simply marks a check in the appropriate column every time he or she rejects a policy statement. At the end of the measurement period, the PAT can pool the data to get a big picture of why policy statements are being rejected.

Benefits of Check Sheets

- Simple to Use
- Easy to Understand
- Time-efficient

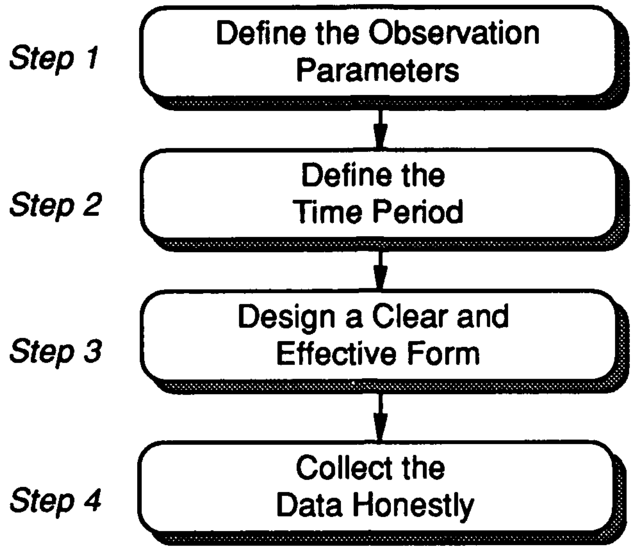
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The simple structure of check sheets makes them very easy to use and user friendly to nearly all participants in the process. Gathering data with a check sheet requires no knowledge of mathematics or experience with quantitative methods. If the person leading the data-gathering effort effectively communicates what should be recorded, anyone who is involved in the process and can count and make check marks can be a successful gatherer of statistical data.

- The simple structure of check sheets also makes them very easy to understand. Check sheets present critical data in a simple format. This format allows managers to easily use the data to analyze their processes.

- Because check sheets are easy to use and understand, they do not require great expenditures of time. Workers and managers can effectively gather and analyze data without investing time in learning new skills and terminology.

Constructing a Check Sheet



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- *Step 1: Define the Observation Parameters* so that everyone involved in data collection knows what they should be recording. Data will only be meaningful if all personnel have the same criteria for recording a "check." When we define parameters, we also ensure that the data will be useful. For example, the parameter "record each time a problem occurs" will not produce as useful data as the parameter "record each time problem A, B, or C occurs." The former parameter will tell you how often problems occurred, while the latter will tell you how often each specific problem occurred.

- *Step 2: Define the Time Period* during which data will be collected. The period can range from hours to weeks or even longer. The period should be long enough to gain a representative sample.

- *Step 3: Design a Clear and Effective Form* that all personnel can understand and use. The columns and rows should be clearly labeled and there should be enough space to collect the data.

- *Step 4: Collect the Data Honestly* to ensure the integrity of the results. Most likely, no one will intentionally introduce inaccurate data. However, people must be strongly encouraged to record events as they actually happen, not as they "usually happen," or how they think they will happen in the future. Remember, you are using check sheets to eliminate the use of subjective opinions and judgments. Recording the data as the events actually occur is necessary to ensure valid, objective data.

Exercise 5-1

Developing a Check Sheet

Exercise 5 -1: Developing a Check Sheet

Scenario: Through the use of a cause and effect diagram (Exercise 4-4) your office has identified numerous potential causes of problems regarding incoming telephone calls. Recall that incoming phone calls created problems by disrupting other work and that customers have complained about the difficulty in reaching staff on the telephone. After identifying potential causes, the next step is to validate your nominations.

Task: As a group, develop a check sheet to record the occurrence frequency of causes identified in the cause and effect diagram in Exercise 4-4.

Discussion Questions:

1. How did you ensure the check sheet will be clear to all personnel?

2. What steps would you take next?

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

PARETO CHARTS

The Pareto Principle

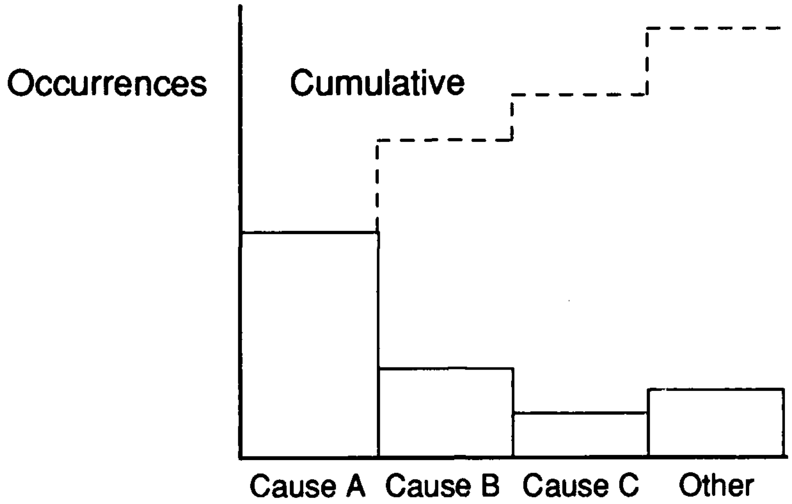
The "Vital Few" and the "Trivial Many"

- The Pareto principle, or the 20-80 principle, states that 20% of the causes – the "vital few" – produce 80% of the results. The other 80% of the causes are the "trivial many," which produce only 20% of the results.
- As applied to the analysis of a process, the Pareto principle states that 20% of the problems are responsible for 80% of the cost of rework.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Vilfredo Pareto (1848-1923), an Italian sociologist and economist, developed the Pareto principle. He originally used the principle to illustrate that 20% of the population controlled 80% of the wealth.
- Applying the Pareto principle to process analysis indicates that not all problems contribute equally to the cost of poor quality. We can achieve dramatic process improvement by correcting the "vital few" problems that cause the bulk of the costs.

What is a Pareto Chart?



Pareto Chart: A vertical bar graph that presents "causes," or problems, in descending order of their impact on a given "effect."

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Pareto charts help us improve quality by presenting process problems in order of their importance.
- The Pareto principle tells us that the most effective way to improve a process is to concentrate on correcting the 20%, the "vital few," and not waste time and resources attempting to correct the other 80%, the "trivial many." However, in keeping with the TQM principle of continuous improvement, you would begin to work on the trivial problems as soon as you solved the "vital few."

Benefits of Pareto Charts

- We use Pareto analysis to distinguish the "vital few" from the "trivial many." This knowledge allows us to efficiently use our resources by attacking those problems with the greatest impact on the process.
- Pareto charts eliminate reliance on guesswork by providing information that allows us to determine which problems must be corrected.
- Pareto charts promote unity of effort by clearly illustrating which problems are most serious.

- Without Pareto analysis, managers often rely on guesswork and "instinct" to determine which problems are serious. They then take action to solve those problems that they have judged to be most serious. Action based on guesswork and "instinct" often results in significant waste of time and resources to correct a problem that in reality has very little impact on the process.
- A Pareto chart illustrates the "vital few" problems that are most severe. This information allows us to concentrate our improvement efforts on the problem areas where we can have the greatest impact.
- Without Pareto analysis, people often are split on which problems are most critical. Pareto analysis promotes unified effort by quantitatively stating which problems are most critical and must be addressed.

Choosing the Comparison Criterion

Problems in a Process

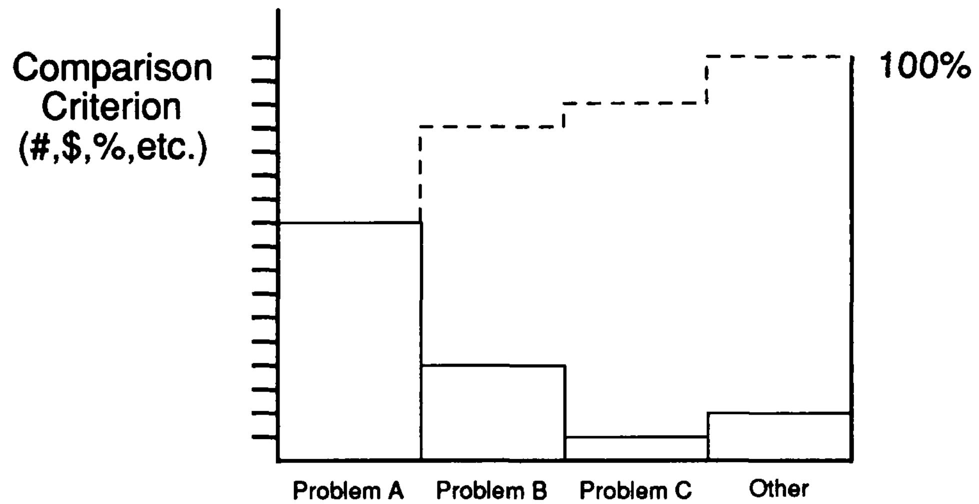
Problem	Frequency of Occurrence	Cost per Ocurrence	Total Cost
Problem A	100/month	$1.00	$100.00
Problem B	10/month	$1.00	$10.00
Problem C	2/month	$10,000.00	$20,000.00

- A comparison criterion is the measure that we use to rank the problems or causes being studied in a Pareto chart.
- Choosing the criterion is a critical step because different criteria may produce dramatically different results.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- A Pareto chart can rank problems according to frequency of occurrence, cost, or any other criterion that illustrates the contribution of each individual problem to the total problem.
- Managers must carefully analyze their processes to determine the most meaningful criterion.
- Clearly, in the above example, if we conduct a Pareto analysis using frequency of occurrence as the comparison criterion, we will conclude that problem A is the most serious. However, if we conduct a Pareto analysis using total cost as the comparison criterion, it is obvious that problem C is the most critical.
- This simple example illustrates an important point. A frequently occurring problem is not always very significant, while a problem that occurs relatively infrequently may be extremely significant in terms of cost or lost time.

Structure of a Pareto Chart



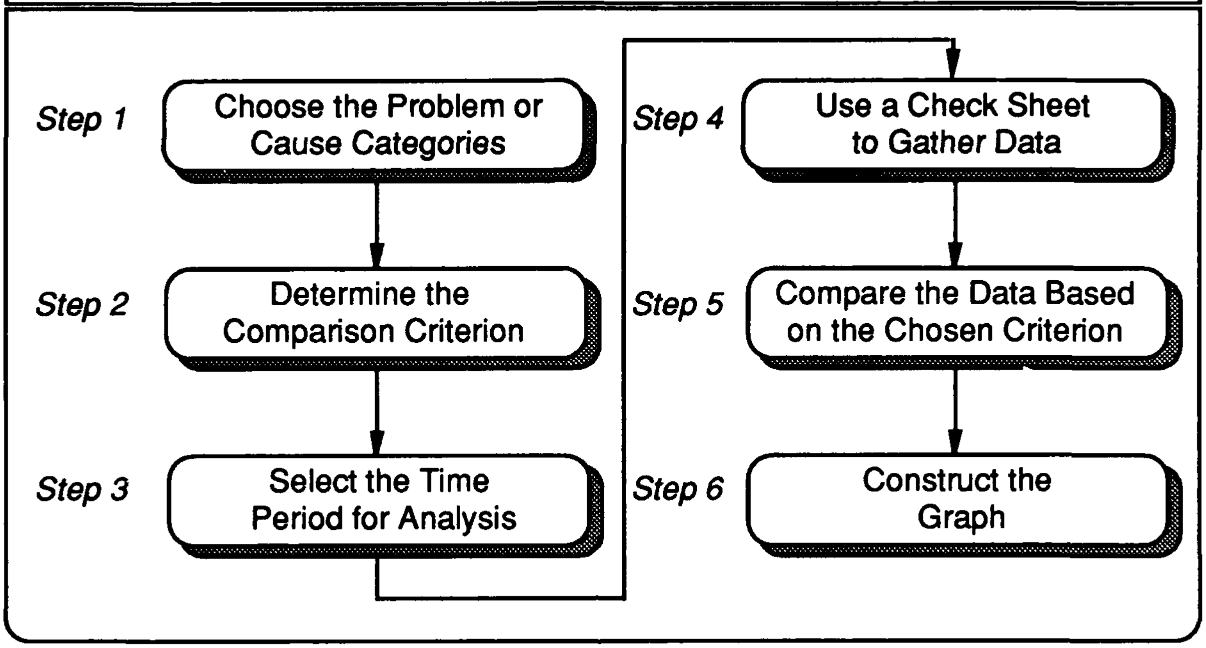
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The horizontal axis represents problems or causes. The vertical axis represents the criterion by which the problems are ranked, usually frequency of occurrence or cost.

- The broken line represents the cumulative percent of the various problems. In other words, from left to right, the broken line is equal to the sum of the vertical bars. Pareto charts are effective tools with or without a cumulative percentage line.

- The structure of a Pareto chart allows you to clearly distinguish the relative impact of each problem; a quick glance at the chart reveals which problem is most prevalent.

Constructing a Pareto Chart



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- *Step1: Choose the Problem or Cause Categories.* Choose the problem categories by soliciting the opinions of people with intimate knowledge of the process or by consulting existing data about process problems.

- *Step 2: Determine the Comparison Criterion.* The comparison criterion may be frequency of occurrence, cost, time lost, or any other standard that will allow individual causes to be viewed by their contribution to the total effect.

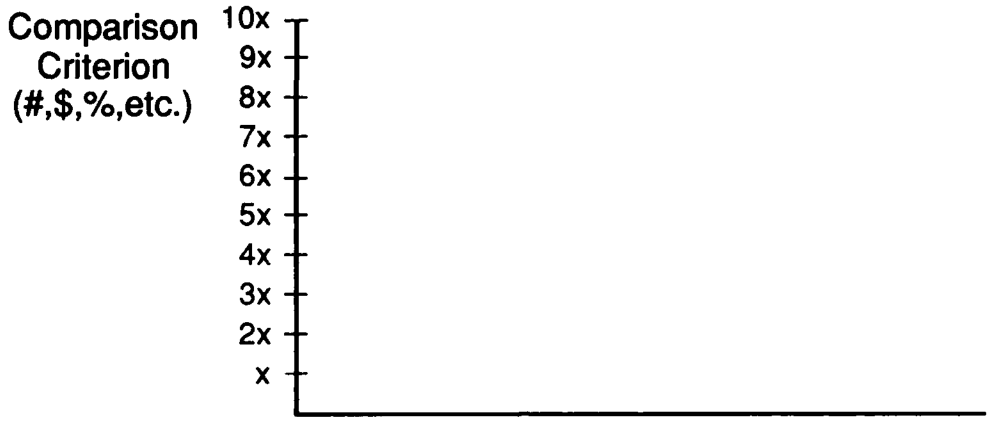
- *Step 3: Select the Time Period for Analysis.* The analysis may cover any relevant time period. When constructing several related Pareto charts, it is best to use the same time period for purposes of comparison.

- *Step 4: Use a Check Sheet to Gather Data.* The check sheet data forms the basis of the Pareto analysis.

- *Step 5: Compare the Data Based on the Chosen Criterion.* To compare the data, apply the comparison criterion to each problem category. For example, problem A occurred 156 times, problem B occurred 92 times, and problem C occurred 53 times; or problem A cost $2,000 per month, Problem B cost $1500 per month, and Problem C cost $1700 per month.

- *Step 6: Construct the Graph.* Set up the vertical and horizontal axes, draw the rectangles representing each problem category, and clearly label all parts. Draw a cumulative percentage line if desired.

Constructing a Pareto Chart

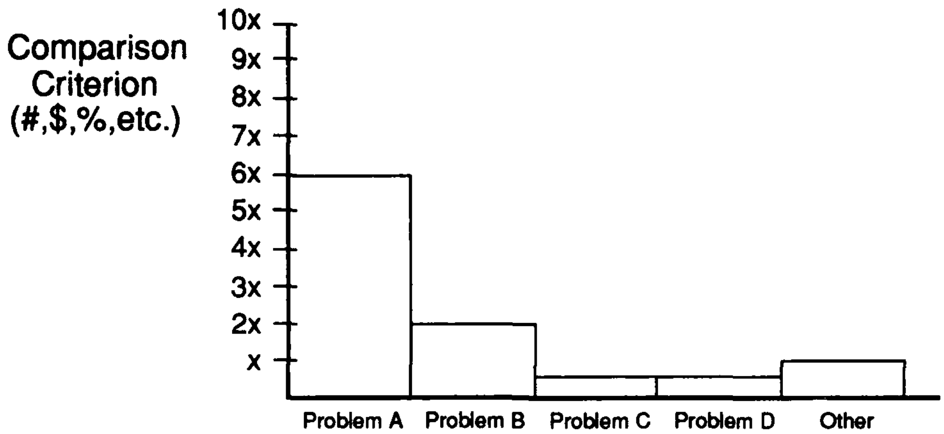


- Set up a graph with vertical and horizontal axes.
- Scale the vertical axis to reflect the comparison criterion.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- To make the chart as easy to read as possible, scale the graph using even multiples. For example, use .1, .2, .3 or 1000, 2000, 3000. Make sure to clearly identify what the units represent (number of occurrences, lost time, cost, etc.).

Constructing a Pareto Chart

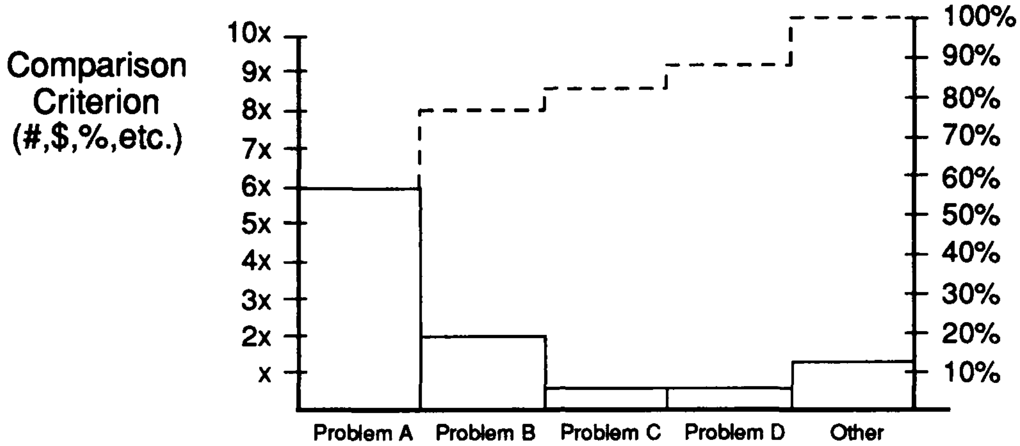


- List the problem categories from left to right along the horizontal axis.
- Draw rectangles for each problem category.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- List the problem categories from left to right along the horizontal axis, beginning with the problem with the highest rectangle.
- The height of the rectangle representing each category corresponds to the category's comparison criterion measurement from the check sheet.
- The least frequent categories should be combined into a category called "other" and illustrated by a box on the far right of the graph.
- The categories should be independent--one category should not be dependent upon another.

Constructing a Pareto Chart



- Draw a vertical axis on the right and scale it from 0% to 100%
- Draw the cumulative percentage line.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- To include a cumulative percentage line, draw a vertical axis on the right side of the chart and scale it from 0% to 100%. Make sure to draw the right axis on the same scale as the left axis. To make sure the scales are the same, add the comparison criterion values of all the problems to get the total comparison criterion value. The total comparison criterion value on the left vertical axis should be the same height as 100% on the right vertical axis.

- Begin drawing the cumulative percentage line at the top of the tallest bar and move upward and to the right in step fashion, adding the height of each bar to the line.

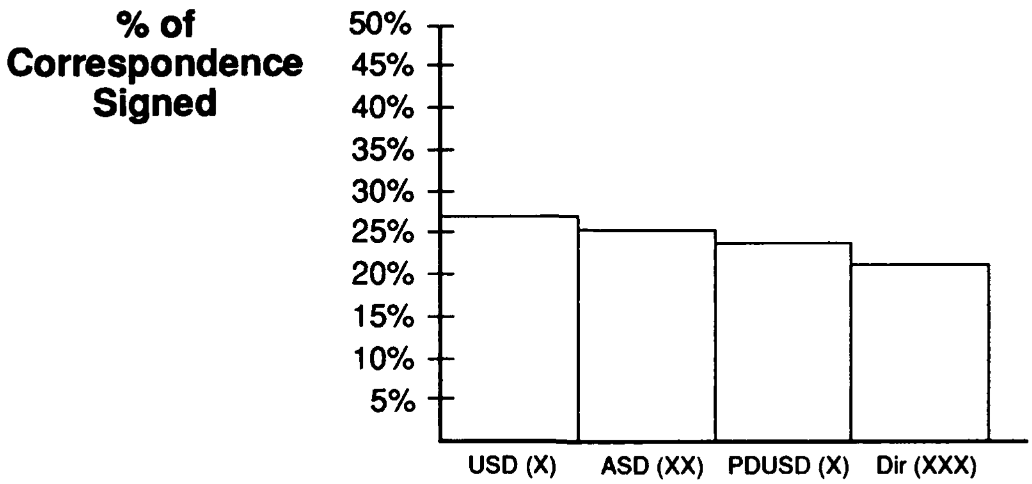
A Hypothetical DoD Example

The Paper Trail

Office	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Total Signatures	% of Signatures
USD (X)	125	125	125	125	505	27
PDUSD (X)	110	110	110	110	454	24
ASD (XX)	115	115	115	115	481	26
Dir (XXX)	91	91	91	91	417	22
Total:					1857	

- Table represents cumulative data from check sheets recording who signed correspondence during one year in all of USD (X).

A Hypothetical DoD Example

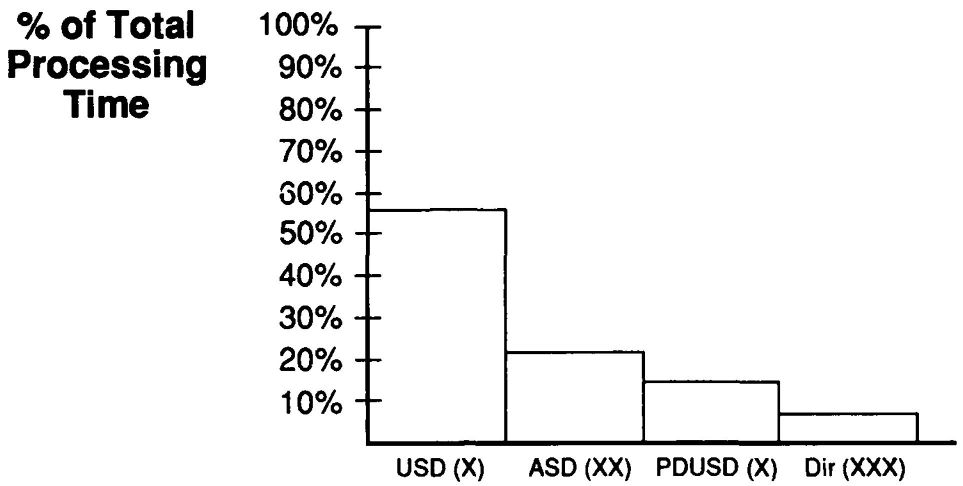


Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The chart above illustrates that there is not a large difference in the number of correspondence signed by each office in the study. No one office is much more overwhelmed by paperwork than any other.
- When a Pareto analysis produces fairly even bars, as in the case above, it is usually necessary to take the analysis to a deeper level.
- In this case, it is necessary to consider how long it takes for a piece of correspondence to pass through the various levels. A further analysis of time required to process correspondence through the signature stage produces the following results (see table on next page).

Office	Processing Days	Signatures	Days x Signatures	% of Total Processing Time
USD (X)	14 days	505	7070	56
PUSD (X)	6 days	454	2724	22
ASD (X)	4 days	481	1924	15
Dir (XXX)	2 days	417	834	7
Total			**12552**	

A Hypothetical DoD Example



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- This chart has been constructed using percent of total processing time (number of signatures multiplied by number of processing days) as the comparison criterion.

- This chart clearly illustrates that most processing time is consumed at the USD (X) level. One obvious recommendation would be to reduce the signature level of correspondence. Based on an actual Pareto analysis of processing time, this recommendation was made and accepted in DoD.

Exercise 5-2

Constructing a Pareto Chart

Exercise 5 -2: Constructing a Pareto Chart

Scenario: The data in this table represent the results of a hypothetical study of interruptions to productive work in an OSD office.

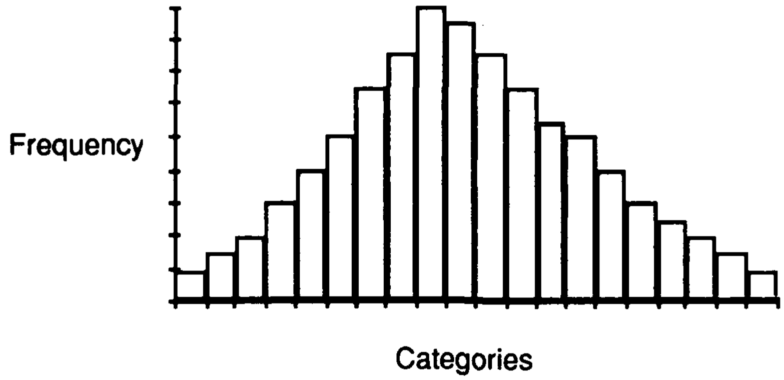
Interruption	Frequency of Occurrence	Avg. Length of Interruption (In Minutes)	Total Interruption Time (In Minutes)
Computer Problems	7	30	210
Telephone Calls	70	2	140
Waiting for Approval	10	10	100
Meetings	9	120	1080
Waiting for Equipment	2	30	60
Birthday Parties	1	30	30
Interviews by Security Personnel	1	30	30

Task: Using the graph paper provided by the instructor, develop a Pareto chart based on the above table. As necessary, refer to the Pareto chart discussion in the previous pages.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

HISTOGRAMS

What is a Histogram?



- Displays distribution of data with bars
- Shows amount of variation in a process
- Identifies sources of variation
- Summarizes, simplifies, and communicates data effectively

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

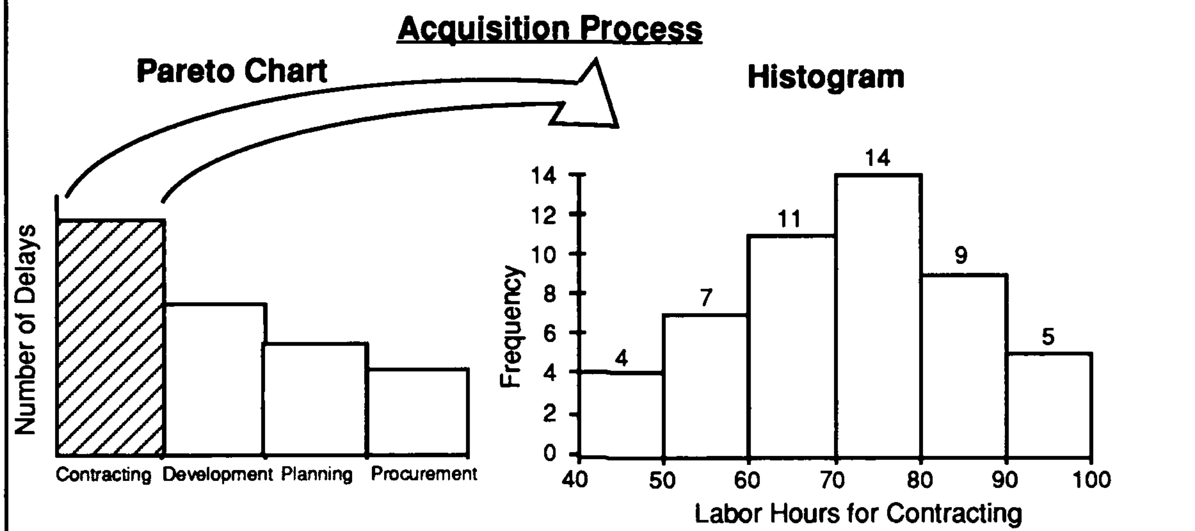
- A *histogram* is a vertical bar graph that depicts the distribution of a set of continuous data. It is a tool that helps keep track of variation by providing a "snapshot" of a process that shows:

  - Spread of measurements
  - How many of each measurement there are.

- The histogram is similar to the Pareto chart in two ways: both display in bar graph form the frequency with which certain events occur, and both chart one variable only. However, there are two main differences between these tools.

  - The Pareto chart can show comparison criterion measurements for process characteristics (qualitative data), for example, meetings, phone calls, and computer problems.
  - The histogram shows variation along a measurement continuum (*quantitative* data, for example, time, temperature, weight, length) for <u>one</u> process characteristic.

What is a Histogram?



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Both a Pareto chart and histogram can be used to study the acquisition process for contracts under $1,000,000.

- As shown in the example above, you can create a Pareto chart to show the number of delays within each of four phases of the acquisition process (for instructional purposes, let's say planning, development, contracting, and procurement). Charting attribute data with a Pareto chart helps to prioritize where to attack problems.

- After prioritizing the problem areas, you can develop a histogram to show the distribution of labor hours within the targeted area (contracting). The histogram will provide you with information about the variation of labor hours within the contracting process.

- Note that the Pareto chart prioritizes *qualitative* or categorical data, while the histogram shows variation along a continuum for *quantitative* data.

-

How to Interpret a Histogram

Peaked (small variability)

Less Peaked (large variability)

Peakedness
Measure of variability - how tall and skinny the distribution is

Skewedness
Measure of variability - how symmetrical the distribution is

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- In interpreting the data, it is often useful to superimpose a curve over the traditional bar graph. This curve may be used to determine how normal the distribution is.

- The shape of the histogram tells you about the nature of the variability that exists within the process and helps to identify the source of variability. *Variability* is the distance from the mean.

- There are two types of variability:

  - *Peakedness* tells you how much variation exists. The more peaked the graphic, the smaller the variation and standard deviation. A wide graph has a greater standard variation and is less stable.

  - *Skewedness* tells you how symmetrical or normal the distribution is. A distribution may be skewed to the left or to the right.

- Three questions can be answered by a quick look at the pattern of the histogram:

  1. Is the process producing a bell-shaped curve?

     - If yes, then the process appears normal and stable, and variations are generally due to random causes.

     - If not, then special causes are influencing the variations.

  2. Is the process centered?

     - The process is well centered when the average of the histogram and the specification midpoint are close together.

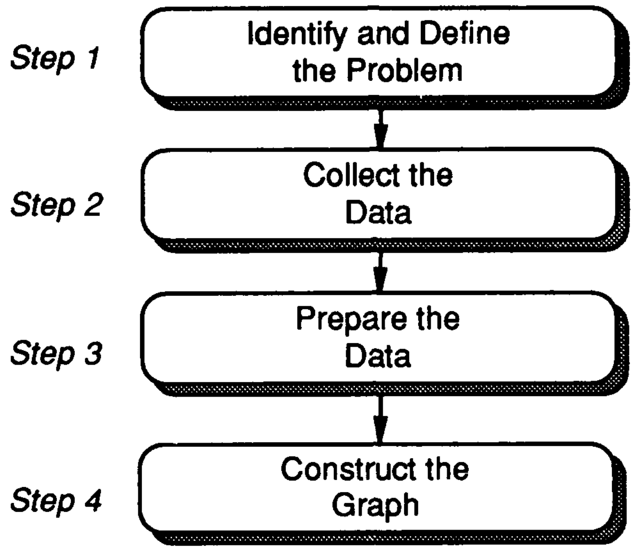
     - The process needs some adjustment when the average of the histogram and the specification midpoint are far apart.

  3. Is the process capable of meeting the specification?

     - The process is capable of meeting the specification if the spread of the graph falls within the specification limits.

     - The process is not capable if the spread falls outside the specification limits.

Constructing a Histogram



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- *Step 1: Identify and Define the Problem.* In constructing a histogram, you must first identify your problem. Everyone must define and agree on the problem, and determine exactly what it is you are measuring. Module IV discusses tools, such as flow charting and cause and effect diagramming, to assist in the problem identification and definition process.

- *Step 2: Collect the Data.* After agreeing upon the problem, you must collect the data. Tips for data collection include the following:

  - The more measurements you collect, the more valid your histogram. *Fifty measurements* are considered a minimum.

  - The validity of the histogram depends upon the uniformity of data collection. Establish guidelines to ensure that data are collected by the same measures each time.

- *Step 3: Prepare the Data.* The next step is to organize the data for display in bar graph form. You will conduct a series of calculations to construct a frequency table.

- *Step 4: Construct the Graph.* The final step involves setting up the graph and plotting the points and bars based on the calculations performed in Step 3.

Constructing a Histogram

Step 3 **Prepare the Data**

a. Count the number of data points in the set of data.

b. Calculate the range for the entire data set.

c. Determine how many bars (class intervals).

d. Calculate the width of each bar.

e. Determine the boundaries and midpoints.

f. Construct a frequency table.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The preparation of data requires a series of steps to construct a frequency table. We will use the example of the distribution of labor hours for contracting, as discussed earlier, to explain how to prepare the data.

Constructing a Histogram

Step 3 Prepare the Data

Number of Labor Hours in Contracting Phase of Acquisition									
77	61	68	83	69	58	78	56	76	86
51	40	84	72	62	53	70	67	85	76
90	63	75	52	71	63	53	74	75	87
98	89	64	79	44	71	55	66	48	92
81	73	82	42	65	88	80	99	78	97

a. Count the number of data points in the data set. (50)

b. Calculate the range for the entire data set. (99 - 40 = 59)

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The first step in preparing the data is to count the number of data points in the data set. In our example above, the number of data points in the set is 50.
- After determining the number of data points, calculate the range.
  - Determine the largest value in the data set. In our example, the largest value is 99.
  - Determine the smallest value in the data set. In our example, the smallest value is 40.
  - The range is equal to the difference between the largest and smallest values in the data set. In our example, the range equals 99 - 40. Thus, the range is 59.

Constructing a Histogram

Step 3 Prepare the Data

Number of Data Points	Number of Bars (Classes)
Under 50	5 - 7
50 - 100	6 - 10
100 - 250	7 - 12
Over 250	10 - 20

c. Determine the number of bars (classes or intervals).

d. Calculate the width of each bar (class width).

Number of bars = 6
Width = *range/bars* ≈ 10

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The third step, c, is to determine the number of class intervals using the table above. The table provides an approximate guideline for dividing the data set into a reasonable number of classes. It is important to choose the right number of intervals for the number of readings. Too few intervals may hide valuable information, while too many intervals may result in a flat histogram.

- The next step, d, is to calculate the class width.

  - Class width is equal to the range, 59, divided by the number of classes, 6. In our example, width = 59/6 = 9.83.

  - In this case, as in most, it is helpful to round off to some convenient number. For our purposes, we will use 10.

  - If the range value is not easily divisible by the number of bars, you may wish to select a different number of bars (from the table) to obtain a more manageable width.

Constructing a Histogram

Step 3 Prepare the Data

Class Number	Boundaries	Interval	Midpoint
1	39.5 - 49.5	40 - 49	44.5
2	49.5 - 59.5	50 - 59	54.5
3	59.5 - 69.5	60 - 69	64.5
4	69.5 - 79.5	70 - 79	74.5
5	79.5 - 89.5	80 - 89	84.5
6	89.5 - 99.5	90 - 99	94.5

e. Determine the boundaries and midpoints.

- The fifth step, e, is to determine the boundaries. Boundaries are necessary for handling data points that fall on the lines between classes. In our case, because the smallest data point is 40 and the width is 10, the first interval would go from 40 to 50, the second from 50 to 60, and so on. But if there is a measurement of exactly 50, we have to decide whether to record it in the first or second interval. Boundaries are set up between the intervals such that no data points can fall on them.

- To set up boundaries:

  - Find the data point with the highest level of significance. The level of significance refers to the degree of accuracy. In the set of numbers, {1, 1.1, and 10}, 1.1 has the highest level of significance. In our example, all data points have the same level of significance. Therefore, we can use any data point.

  - Then calculate half of the value of the right most decimal place of that data

point. The right most decimal place of a two-digit number less than 100 is the unit position, which has a value of 1. Half of 1 is .5, which is the number we use to calculate the boundaries.

- Subtract this value from the endpoint of each interval. In our example, the boundaries for the first class become 39.5 and 49.5. Now, no data points can fall on the boundaries.

• From the boundaries, you can determine which data points will fall within the interval. For example, the data points 40 through 49 will fall in the first class, 50 through 59 in the second class, and so on.

• The next step is to determine the midpoint for each class. The midpoint may be used to label each bar in the graph. The midpoint is calculated as follows:

- Divide the width in half. In our example, 10/2 = 5.

- Add the result to the lower boundary of each interval. In our example, for the first interval, 39.5 + 5 = 44.5; for the second interval, 49.5 + 5 = 54.5; and so on.

• The chart above shows the boundaries, intervals, and midpoints for each class or bar.

Constructing a Histogram

Step 3 Prepare the Data

Class Number	Boundaries	Interval	Midpoint	Frequency	Total
1	39.5 - 49.5	40 - 49	44.5	IIII	4
2	49.5 - 59.5	50 - 59	54.5	~~IIII~~ II	7
3	59.5 - 69.5	60 - 69	64.5	~~IIII~~ ~~IIII~~ I	11
4	69.5 - 79.5	70 - 79	74.5	~~IIII~~ ~~IIII~~ IIII	14
5	79.5 - 89.5	80 - 89	84.5	~~IIII~~ IIII	9
6	89.5 - 99.5	90 - 99	94.5	~~IIII~~	5
				TOTAL	50

f. Construct a frequency table.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

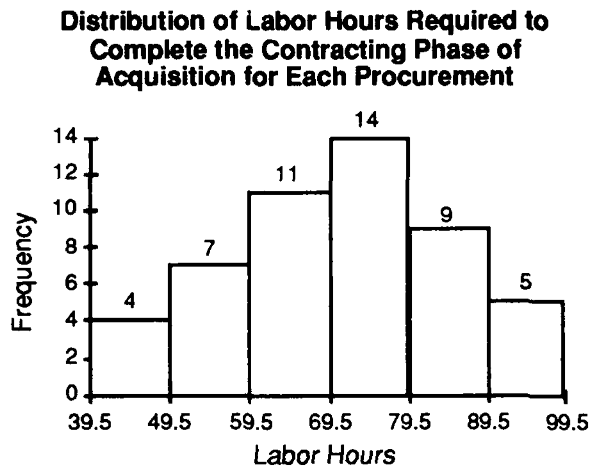
- The final step in the preparation of data is to construct a frequency table. The frequency table provides a tally of the data in each class interval. Using the raw data, determine how many of the data points fall within each interval. In our example, the data points 40, 42, 44, and 48 all fall within the first interval, thus the frequency is 4.

- To check your tally, make sure the total equals the number of data points, N. In our example, note that the total tally, 50, equals the number of data points in the set (50).

- As seen above, the frequency table is actually a histogram in tabular form.

Constructing a Histogram

Step 4 Construct the Graph



a. Mark and label the vertical scale.

b. Mark and label the horizontal scale.

c. Draw in the bars according to the frequency table.

d. Label the histogram.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The first step in constructing the graph is to mark and label the vertical scale.
  - Refer to the frequency table to determine the highest frequency. Mark proportionally spaced units along the vertical axis from 0 at the origin to the largest frequency value, which is 14 in our example.
  - Label the vertical axis, in our example, "Frequency."
- Next, mark and label the horizontal scale.
  - Using the boundaries calculated in Step 3 and beginning at the origin, mark the intervals along the horizontal axis. In our example, begin at the origin with 39.5. Then mark proportionately spaced intervals and label them with the boundaries: 49.5, 59.5, etc. You may also label the bars with the midpoints.
  - Next, label the horizontal axis with the process characteristic being measured, in this case, "Labor Hours."

- The third step, c, is to draw in the frequency bars. Use the frequency table to determine the height of each bar. In our example, the tally for the first class is 4 units high; for the second class, 7 units high; and so on. Mark the frequency tally on top of each bar.

- The final step is to label the histogram. Choose a label that identifies the context of the data. In our example, we chose "Distribution of Labor Hours Required to Complete The Contracting Phase of Acquisition for Each Procurement."

Exercise 5-3

CONSTRUCTING A HISTOGRAM

Exercise 5-3: Constructing a Histogram

Scenario: You are studying the Controlled Correspondence process in your office. In an attempt to understand why there is overdue correspondence, you track how long it takes for controlled correspondence to go through the process. You then display the data in histogram format to understand the variation in the process.

Task: Construct a histogram which shows the variation in processing time in the Controlled Correspondence process, using the data shown on the next page.

Discussion Questions:

1. What does the shape of the histogram tell you about the process?

Exercise Data

Constructing a Histogram

39	60	20	47	51	48	57	78	50	44
79	46	85	21	37	61	7	37	29	63
78	10	28	65	3	55	88	62	56	64
31	71	70	53	99	68	15	22	76	43
50	54	25	38	80	21	54	75	35	74
72	51	Ø	52	67	53	69	33	45	67
72	55	92	32	48	33	57	51	58	68
32	66	41	66	17	47	23	42	44	91
65	56	19	46	25	58	59	43	52	73
40	82	45	89	49	36	52	98	12	88

Histogram Construction/Interpretation Tips

CONSTRUCTION	*INTERPRETATION*
1. Use equal width intervals. 2. Don't use open intervals. 3. Don't make breaks in vertical or horizontal scales. 4. Be sure to select the proper number of intervals. 5. Keep the graph simple.	1. Don't expect every distribution to follow a bell-shaped curve. 2. Be suspicious of accuracy of data if classes suddenly stop at one point without previous decline. 3. Look for twin peaks as indicator of data from two or more sources.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- In *constructing* a histogram you must be careful about several items so that the histogram will tell the story of the data it represents.
- In *interpreting* a histogram there are several items, such as the shape of the distribution, to look at to understand what the data are telling you.

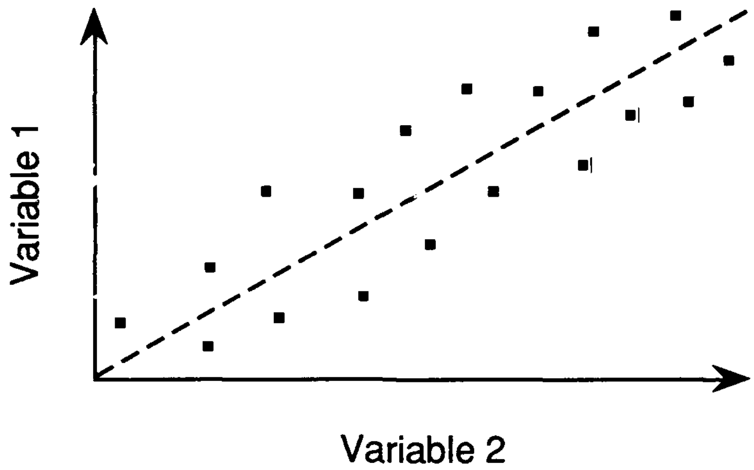
Discussion Questions:

- Discuss why each construction tip is important in accurately representing the data. Draw examples of "bad" graphs to illustrate the points.
- What would a bell-shaped curve tell you about the process? What about a curve that is not bell shaped?
- Why would twin peaks signal data from two different sources? What could be the different kinds of sources?

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

SCATTER DIAGRAMS

What is a Scatter Diagram?



A scatter diagram shows the *relationship* between one variable and another.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- A scatter diagram is used to:
  - Show the relationship between two variables
  - Detect a pattern as two variables change over time
  - Examine a possible cause and effect relationship.
- A scatter diagram can be used to test the strength of the relationship between two variables, but it *cannot be used to prove that one variable causes the other.*
- The horizontal axis (x-axis) represents the measurement values of one variable, and the vertical axis (y-axis) represents the the measurements of the second variable.
- A scatter diagram differs from a histogram and Pareto chart in that two variables are studied in a scatter diagram, while only one variable is studied in a histogram or Pareto chart.

What is a Scatter Diagram?

Examples of Variables that are Related:

- Quality and Productivity
- Number of Cars on the Key Bridge and Time of Day
- Quality and Customer Complaints
- Hemline and Economy

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- A scatter diagram is used to study the relationship between two variables, such as:
  - *Quality and Productivity.* The old myth is that as quality increases, productivity decreases. Deming and other TQM experts, on the other hand, say that as quality increases, so does productivity. A scatter diagram can be used to determine how quality and productivity are related.
  - *Number of Cars on the Key Bridge and Time of Day.* A scatter diagram can be used to show how the number of cars on the Key Bridge increases or decreases depending on the time of day.
  - *Quality and Customer Complaints.* A scatter diagram can be used to show how the quality of a product or service affects the number of customer complaints.
  - *Hemline and Economy.* A scatter diagram can be used to show the relationship between the economy and hemlines. Though a relationship

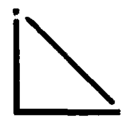
exists, it is clear that the economy does not cause the hemlines to rise and fall, nor does the hemline cause the economy to rise and fall. Thus, though scatter diagrams are used to study the relationship between two variables, *they cannot be used to prove causation.*

How to Interpret a Scatter Diagram

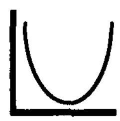
Types Of Correlations

- POSITIVE

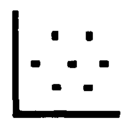
- NEGATIVE



- NONLINEAR



- NONE



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- A scatter diagram is used to test the strength of the relationship, or *correlation*, between two variables.

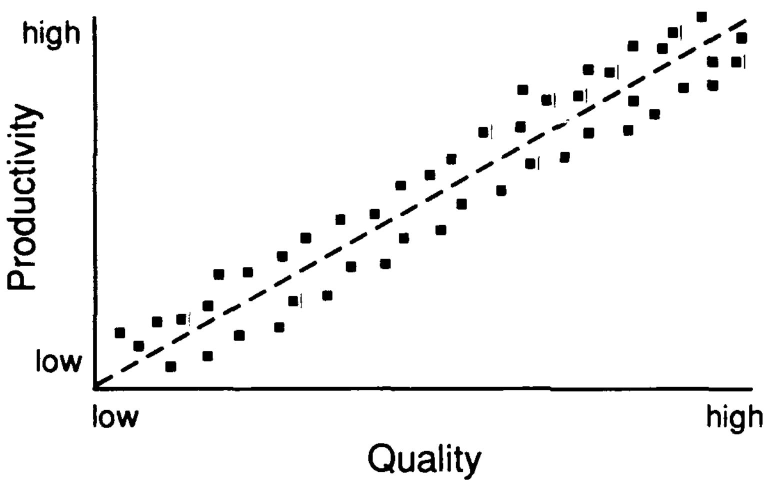
- The direction and tightness of the plotted points or cluster gives you a clue as to the strength of the relationship between the variables. The more the cluster resembles a straight line, the stronger the relationship between the variables. A straight line would mean that every time one variable changes, the other changes by the same amount.

- A "line of best fit" estimates the shape of the plotted points. It is usually determined mathematically, but for our purposes, plotting the line by "eye" is adequate.

- There are four types of correlations that characterize the strength of a relationship: positive, negative, nonlinear, and none. We will use the previous examples to explain each.

How to Interpret a Scatter Diagram

Positive Correlation



Variables change in the same direction.

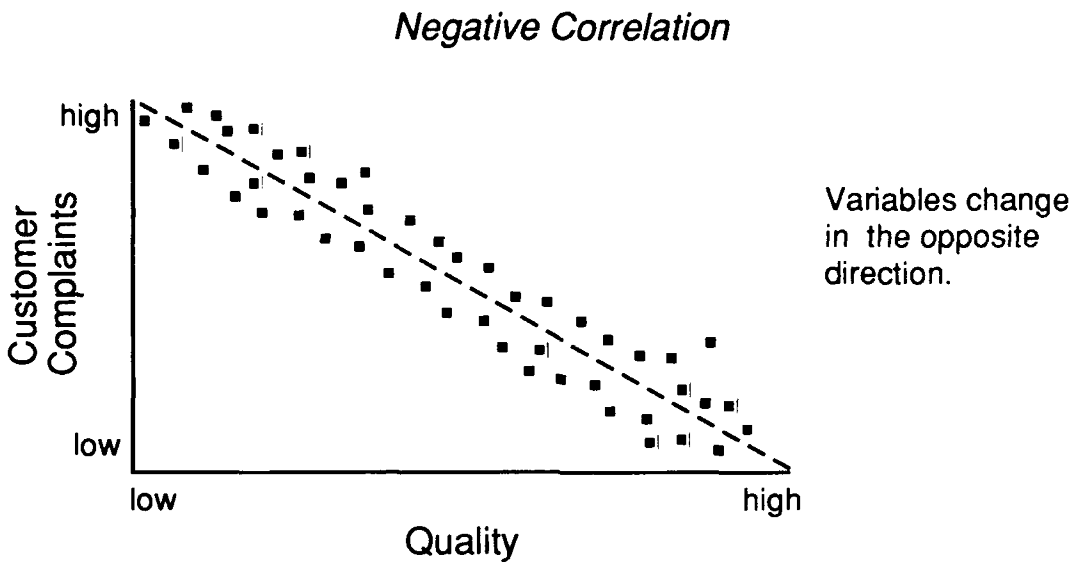
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- In this example, notice how the plotted points form a clustered pattern around a diagonal line. As the x-value, quality, increases, so does the y-value, productivity.
- When both variables change in the same direction, the relationship is referred to as a *positive correlation.*

Discussion Question:

Name some examples of a positive correlation.

How to Interpret a Scatter Diagram



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

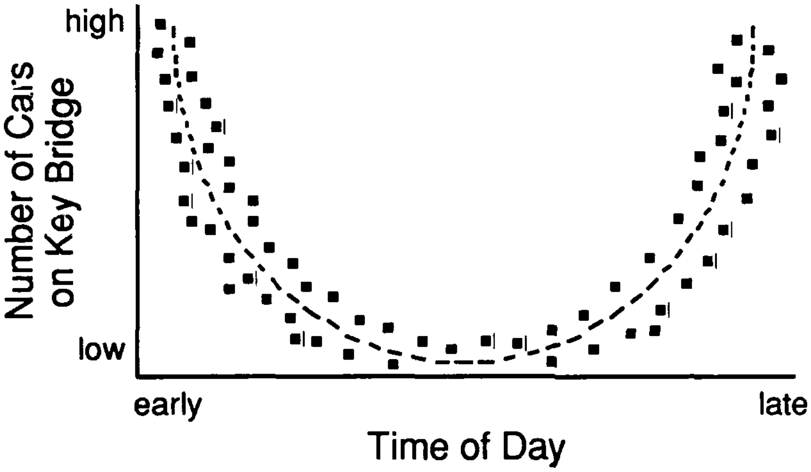
- In this example, notice how the plotted points form a clustered pattern around a diagonal line, as in the previous example. In this case, however, the line is slanted in the other direction. As the x-value, quality, increases, the y-value, customer complaints, decreases.
- When the variables change in the opposite direction, the relationship is referred to as a *negative correlation.*

Discussion Question:

Name some examples of a negative correlation.

How to Interpret a Scatter Diagram

Nonlinear Correlation



Variables follow a pattern that does not result in a straight "line of best fit."

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

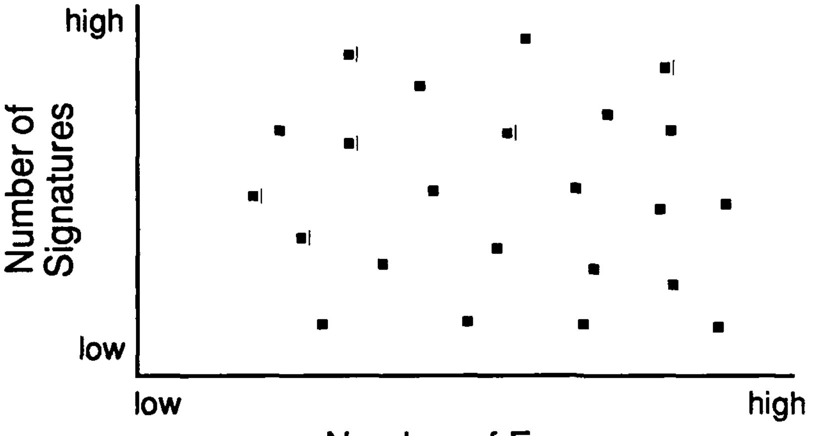
- This example differs from the previous two because, though the they form a pattern, the plotted points are not centered around a *straight* "line of best fit." The number of cars on the Key Bridge decreases from a high in the early hours of the day to a low at midday. The number then increases to a high value at the end of the day.
- When there is a definite relationship between the two variables but the pattern does not fit a straight line, the relationship is referred to as a *nonlinear correlation.*
- Non-linear patterns tend to suggest a better probability of cause-effect relationships than linear correlation.

Discussion Question:

Name some examples of a nonlinear correlation.

How to Interpret a Scatter Diagram

No Correlation



Variables show no discernible pattern.

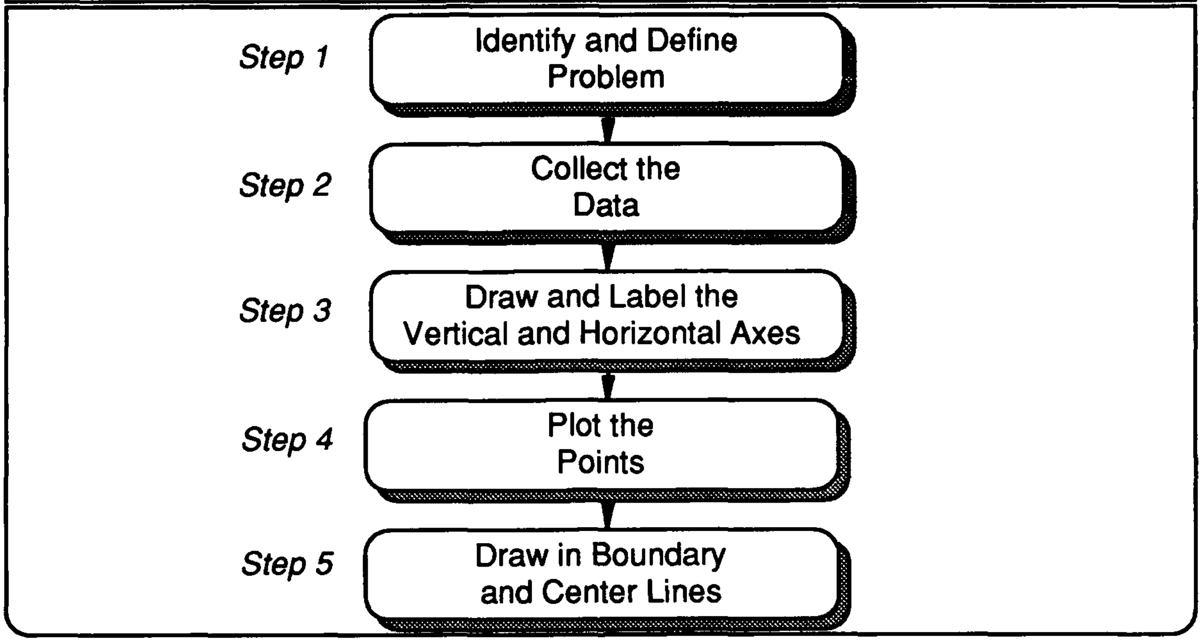
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Suppose you are attempting to streamline the travel request process. Your study team finds that the errors on the forms are holding up the process. You suspect that the number of signatures may contribute to the problem. You could create a scatter diagram to test the possible relationship. As seen in the example above, the plotted points do not form a cluster around either a straight line or a nonlinear figure. There is no relationship between the number of errors and the number of signatures. Thus, you will have to look elsewhere for possible causes of the problem.
- When there is no discernible pattern, the variables have *no correlation.*

Discussion Question:

Name examples of variables that have no correlation.

Constructing a Scatter Diagram



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- *Step 1: Identify and Define the Problem.* In constructing a scatter diagram, you must first identify your problem. Everyone must define and agree on the problem and determine exactly what it is you are measuring. Module IV discusses tools, such as flow charting and cause and effect diagramming, to assist in the problem identification and definition process.

- *Step 2: Collect the Data.* After agreeing upon the problem, you must collect the data. Tips for data collection include the following:

  - The more measurements you collect, the more valid your scatter diagram. Fifty measurements are considered a minimum to show any trend or correlation.

  - The validity of the scatter diagram depends upon the uniformity of data collection. Establish guidelines to ensure that the data are collected by the same measures each time.

- *Step 3: Draw and Label the Vertical and Horizontal Axes.* In the third step, mark the selected scales based on the range of values.

- *Step 4: Plot the Points.* In this step, plot the values for each sample at the intersecting points of variables x and y.

- *Step 5: Draw in the Boundary and Center Lines.* The final step is to draw in the upper and lower boundary lines and the center "line of best fit." The boundary lines are used to draw the center line.

- To illustrate the process, we will construct a scatter diagram for the following example.

  You are studying the approval process for a number of forms in your office. You suspect that the number of signatures required may affect the length of the process. You construct a scatter diagram to determine the relationship between the number of signatures and the length of the approval process.

Constructing a Scatter Diagram

Step 2 Collect the Data

Sample	Variable X: Number of Signatures	Variable Y: Length of Approval Process
1	1	2 days
2	4	8 days
3	6	12 days
.		
.		
.		
50	3	6 days

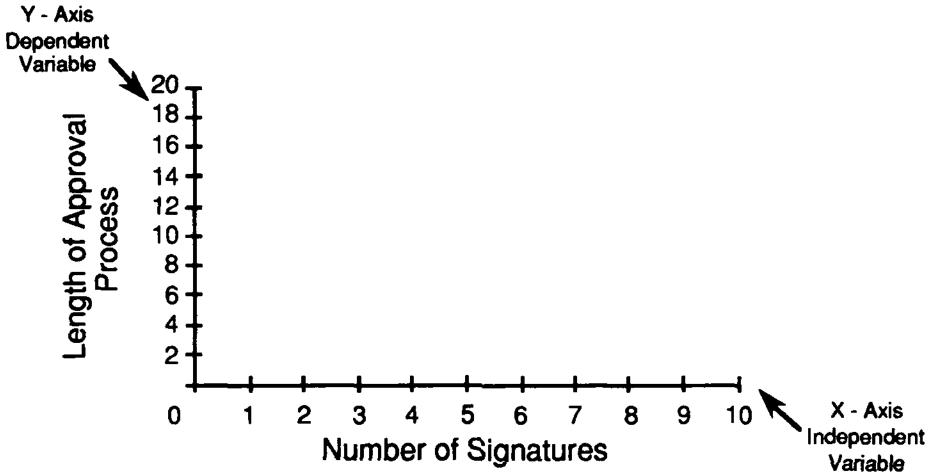
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- After defining the problem, you must collect the data. Scatter diagrams differ from other techniques because they deal with two variables, rather than just one. When data are gathered, there must be an ability to record the measurements of both variables for each sample.

- The data must be *collected and recorded in pairs.* For each sample, record the measurements of both variables in a table or check sheet, as illustrated above.

Constructing a Scatter Diagram

Step 3 — Draw and Label the Vertical and Horizontal Axes

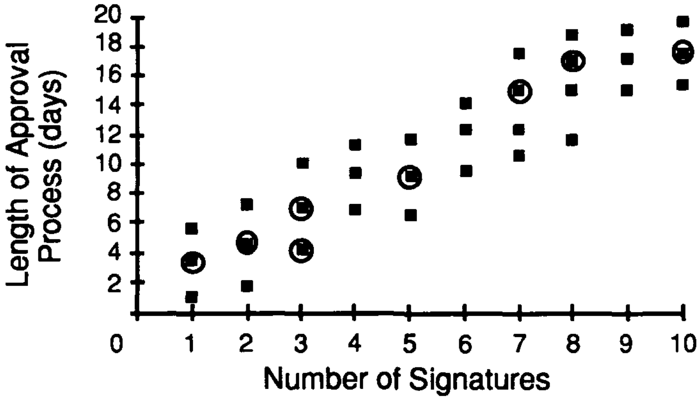


Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Next, examine the range of values for the x and y variables in order to determine the appropriate scale to accommodate the ranges.
- The variable that is being investigated as the possible "cause" is the *independent variable* and is plotted on the horizontal scale. The "effect" variable is the *dependent variable* and is plotted on the vertical scale.
- Draw the horizontal and vertical axes of the diagram. Mark off the selected values on each axis. The values should get higher as you move up or to the right on each axis.

Constructing a Scatter Diagram

Step 4 Plot the Points

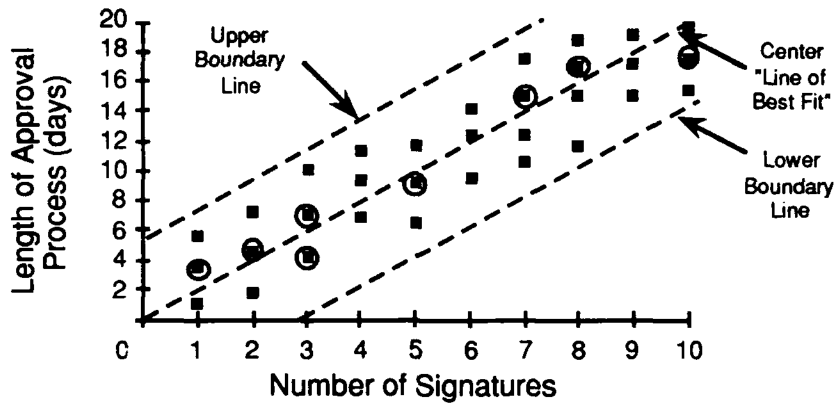


Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Plot the values for each sample at the intersecting points of the x and y scales.
- If you find a value being repeated, circle that point each time the value is repeated.

Constructing a Scatter Diagram

Step 5 Draw in Boundary and Center Lines



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Next, draw in the upper and lower boundary lines along the outer regions of the scatter of data points.

- Finally, use the boundary lines to draw the center line, referred to as the "regression line" or "line of best fit." This line is located halfway between the boundaries. Plotting the line is an attempt to average out both the number and distance for plot points. That is, the distance from the center line of all the points above that line should equal the distance from the center line of all the points below the line.

- If there is a positive or negative correlation, the center line will be straight. If the correlation is non-linear, the line will be curved. If there is no correlation, you will not be able to discern boundary or center lines.

- There are mathematical techniques that can be used to more accurately calculate the "regression equation" for the "line of best fit." However, for this kind of analysis, plotting the center line by "eye" is adequate. The important point to remember is that if a center line can be fitted to a scatter diagram, it will be be possible to interpret the data.

Scatter Diagram Construction/Interpretation Tips

CONSTRUCTION	*INTERPRETATION*
• Data must be collected in pairs.	• A scatter diagram can show a relationship or correlation between two variables, but it *cannot prove causation.*

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

Exercise 5-4

CONSTRUCTING A SCATTER DIAGRAM

Exercise 5-4: Constructing a Scatter Diagram

Scenario: You are studying the Controlled Correspondence process in your office. You suspect that the number of rewrites may contribute to delays in processing time. You decide to study the number of rewrites for overdue packages. You collect data to compare the number of days overdue and the number of rewrites.

Task: Construct a scatter diagram to study these variables: days overdue and number of rewrites. Use the collected data shown in the table on the following page. (For exercise purposes, a full data set, minimum 50, is not shown.) Then draw in the boundary and center lines.

Discussion Questions:

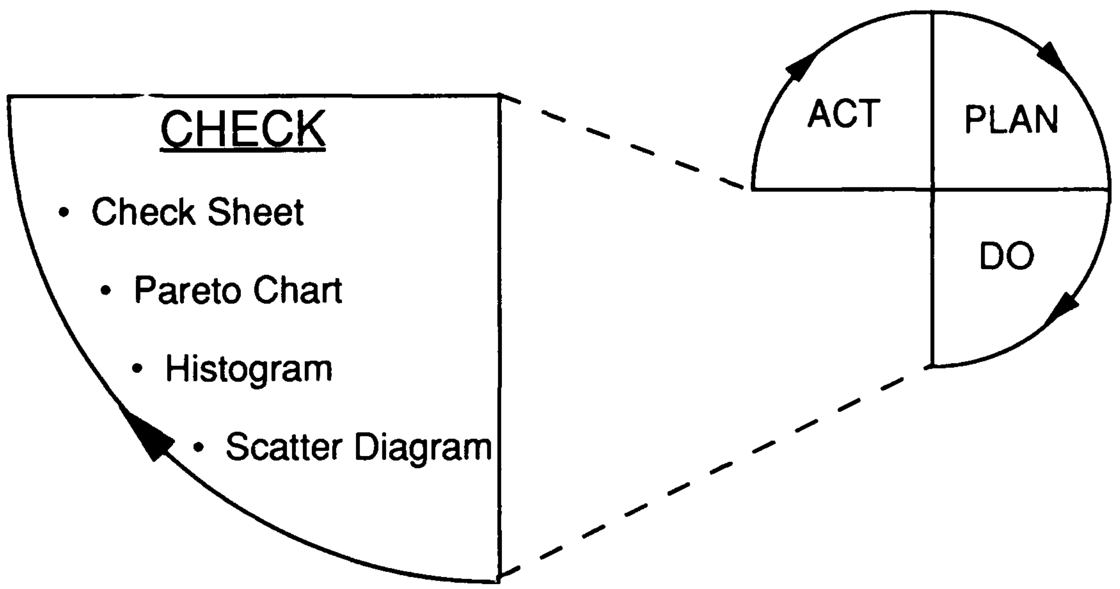
1. What type of correlation exists?

2. How would this information help you understand the process? What changes, if any, would you investigate?

Exercise 5-4: Constructing a Scatter Diagram

Sample	Variable X: Days Overdue	Variable Y: Number of Rewrites
1	5	3
2	20	9
3	13	7
4	19	7
5	1	0
6	13	5
7	7	3
8	12	5
9	3	2
10	16	6
11	24	9
12	6	4
13	10	6
14	2	1
15	17	6
16	15	6
17	25	10
18	3	1
19	10	4
20	20	8
21	17	5
22	22	7
23	7	4
24	9	5
25	22	8

The Use of Tools in the Check Step



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- In review, the Check Step in the PDCA Cycle is the analysis phase. In this phase, you will validate or contradict intuition and previous experience based on the analysis of data.

- Several quantitative methods, as you have learned, are used to analyze data for the purposes of data-based decision making:

  - Check sheet
  - Pareto chart
  - Histogram
  - Scatter diagram
  - (Run chart and control chart, are covered in Module VI).

- These tools are useful for summarizing large amounts of data to determine trends. They graphically depict a process, quickly highlighting information about the distribution and stability of a process.

Selection of Tools in the Check Step

Number of Variables	Type of Data	
	Qualitative	Quantitative
1	Pareto	Histogram
2	————	Scatter Diagram

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- The key in the check phase is the selection of tools--knowing when to use what tool.
- As discussed earlier, the *check sheet* is used to collect and organize data as a preliminary step to the construction of Pareto charts, histograms, and scatter diagrams.
- *Pareto charts and histograms* are used to study one variable. The difference between the two tools is that the *Pareto chart* is used for qualitative data and the *histogram* is used for quantitative data.
- A *scatter diagram* is used to study two variables, each with continucus data points.

Selection of Tools – Check Sheet

Personnel Turnover

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Total
GS 3 - 5	卌	卌卌	卌卌卌卌卌	卌卌卌卌	60
GS 6 - 10	III	III	IIII	II	12
GS 11 - 15	I	II	I	I	5
GM13 - 15	I	I	0	I	3
SES	I	0	0	I	2
SES (PA)	III	IIII	卌	III	15

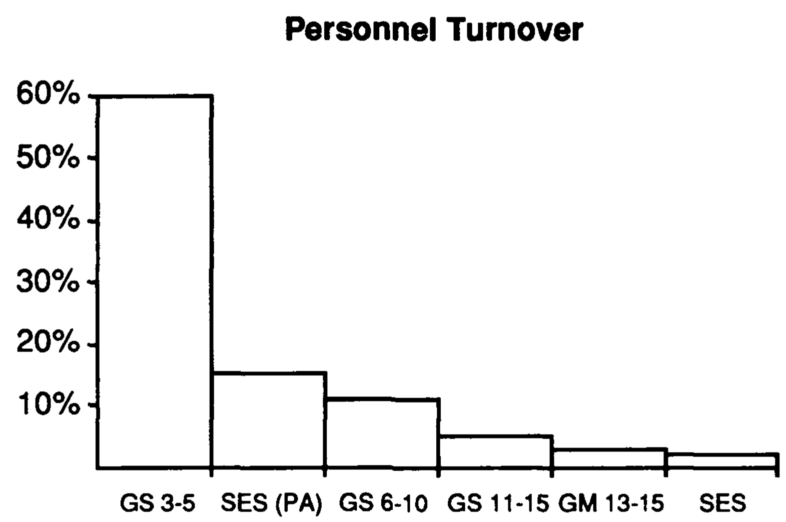
Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Consider the following situation.

  You think your organization has a problem with turnover. You are unsure how to tackle the problem because you do not fully understand the problem. You create a check sheet to track personnel turnover by grade and quarter, as shown above. The information in the chart provides you with general trend information.

- The following pages show how you could use a Pareto chart, histogram, and scatter diagram to more clearly understand the situation.

Selection of Tools -- Pareto Chart

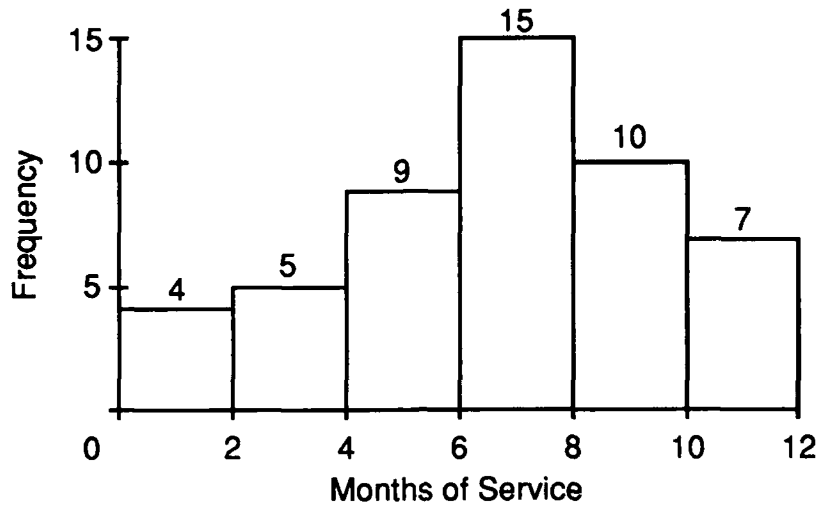


Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- First, you could use a Pareto chart to prioritize your problems.
- This Pareto chart shows that the highest percentage of turnover is occurring in the GS 3 - 5 positions.
- Thus, the Pareto chart helps you to quickly focus on target areas for improvement.

Selection of Tools -- Histogram

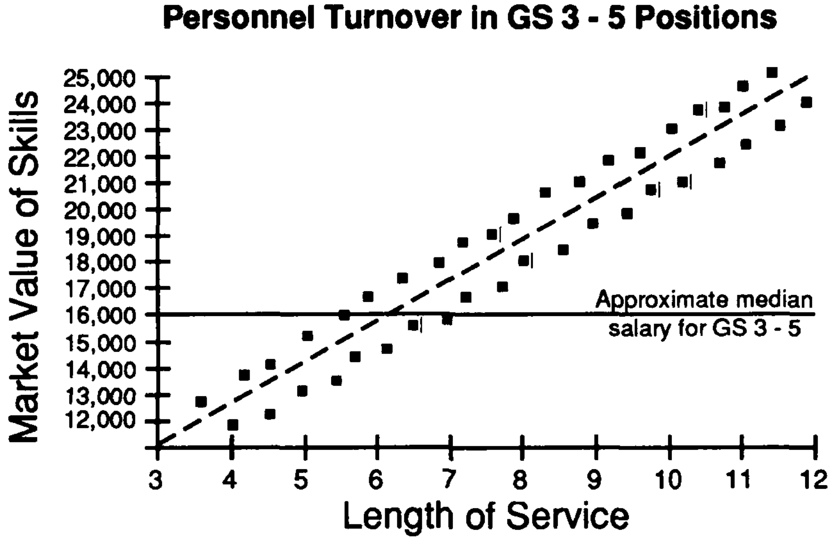
Personnel Turnover in GS 3 - 5 Positions



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- After determining a focus area using the Pareto chart, you could use a histogram to study the turnover of your target area, GS 3 - 5 positions.
- This histogram shows the variation of turnover by months of service. The graphic reveals that the highest frequency of turnover occurs between the sixth and eighth months of employment.

Selection of Tools – Scatter Diagram



Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

- Finally, you could use a scatter diagram to understand why individuals are leaving. Perhaps you suspect that the GS 3 - 5 job incumbents are leaving because they are drawn away by increasing market value for their acquired skills.

- To test your theory, you could plot the correlation between length of service and market value of skills.

- The scatter diagram above shows that there is a positive correlation between length of service and the market value of skills.

- Notice the line drawn across the graph at the $16,000 mark. This line represents the approximate median salary for GS 3 - 5 positions. Note that the break point occurs at six months. As job incumbents enter their seventh month, they have developed their skills to a level that commands a higher market value than their current salary in the federal government.

- Remember that the scatter diagram only shows correlation and does not prove causation.

MODULE SIX

CHECKING AND ACTING: CONTROL CHARTS AND RUN CHARTS

Module Six Objectives

Upon completion of this module, participants will be able to:

- Explain the design concept of the run chart.
- Construct and employ run chart methodology to record and interpret DoD process data.
- Explain the design concept of the control chart.
- Compare and contrast run charts and control charts.
- Calculate and determine control limits on control charts.
- Distinguish between special and common causes in a DoD process.
- Identify processes in a state of control versus an uncontrolled state.
- Explain courses of action for special causes and common causes of DoD process variation.
- Describe common management actions in response to process variation causes and why they are usually misguided.

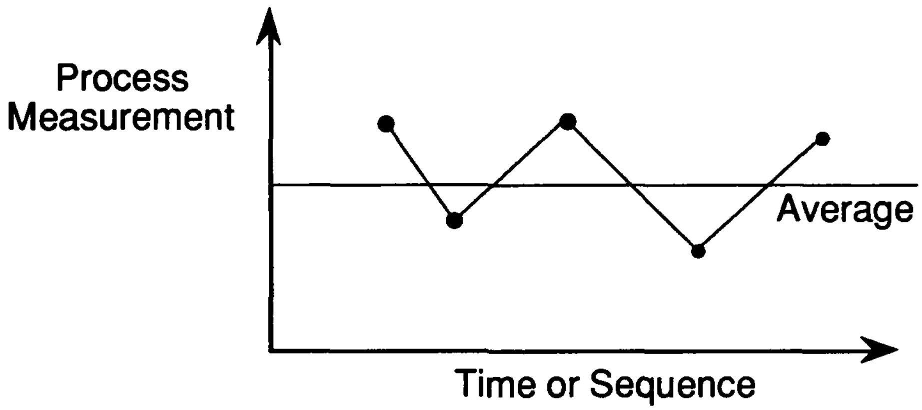
Checking and Acting: Control Charts and Run Charts

- The purpose of this module is to introduce you to run and control charts and to show you how to use these tools in process control.

- The objectives for the module are shown above.

What Is a Run Chart?

A run chart is a line graph that shows data plotted over time.



Checking and Acting: Control Charts and Run Charts

- A run chart is a line graph of process performance over time.
- The vertical axis is some measure of performance for the process.
- The horizontal axis is a time or sequence scale.
- Each data point indicates the measurements or quantity observed or sampled at one point in time.
- The data points are connected for easy use and interpretation.

Why Use a Run Chart?

- **Summarize**
- **Display Trends**
- **Monitor**
- **Before and After Analysis**

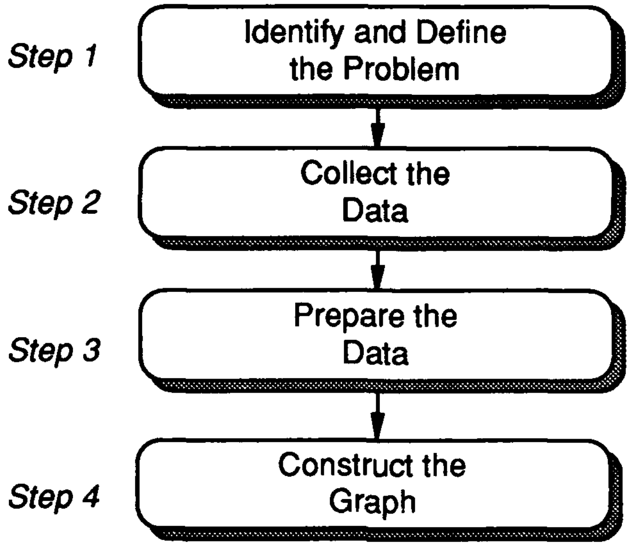
Checking and Acting: Control Charts and Run Charts

- Run charts are used most frequently to analyze data in the Check phase of the PDCA cycle.

- You may use a run chart to:

  - *Summarize* large amounts of data.
  - Display *trends* within observation points over a specific period of time.
  - *Monitor* a process to see if the long range average is changing.
  - Show the effects of corrective action, a *before and after* chart.

Constructing Run Charts



Checking and Acting: Control Charts and Run Charts

- *Step 1: Identify and Define the Problem.* As discussed earlier, asking the right question is critical to getting the right answer.
  - For example, consider the problem of misrouted letters in a large office. One approach to investigating this problem is to study errors in addressing letters in the mailroom. However, by focusing on errors in addressing letters, we might be measuring a cause rather than an effect.
  - A better approach is to study the total misroutings that occur in the office. By measuring the total misroutings, we may find several contributing causes. These causes would have been missed if we only looked at addressing errors.
- *Defining the process factor to be measured* is an important part of asking the right question. If we suspected that misroutingss were determined to a great extent by volume of delivery, but wanted to eliminate the effects of volume, then defining the measure in terms of percent of total deliveries might be more indicative of misroutings due to effects other than volume.

- *Step 2: Collect the Data.* Remember to follow the data collection and sampling techniques learned earlier in the course.
- *Step 3: Prepare the Data.* After collecting the data, determine the measure and calculate the average. The following pages describe these activities.
- *Step 4: Construct the Chart.* Finally, plot the measures and the average on the chart.

Constructing Run Charts

Step 3 Prepare the Data

a. Determine the type of measure

Day	***Frequency***	***Relative Frequency*** (Percentage)
1	1	2.0%
2	1	2.0%
3	12	23.5%
4	9	17.6%
5	6	11.8%
6	12	23.5%
7	8	15.7%
8	2	3.9%
Total	51	100%

b. Calculate the mean

	51/8 = **6.38**	100%/8 = **12.5%**

Checking and Acting: Control Charts and Run Charts

- *Determine the type of measure.* The first step in preparing the data is to determine if you want to use frequency or relative frequency data. Which measure you choose depends on what you are trying to show with the data.
  - *Frequency* is the number of times each activity occurrs.
  - *Relative frequency* provides a comparison or percentage of the frequency to the total number of ocurrences.
- To calculate the relative frequency, divide the frequency by the total number of occurences, and convert to a percentage.
- Consider the mail room example. Suppose you track the number of misroutings per day, as shown in the chart above
  - The frequency is the number of misroutings per day. In the example above, the frequency for day 1 is 1.

- The relative frequency or percentage is the number of misroutings for the day (frequency) divided by the total number of misroutings for all 8 days, converted to a percentage. In the example above, the total number of misroutings is 51. So for day 1, the relative frequency is (1/51) x 100 = 2. 0%.

- *Calculate the Mean.* Recall that the mean is equal to the sum of the measurements divided by the total number of measurements. In the example above:

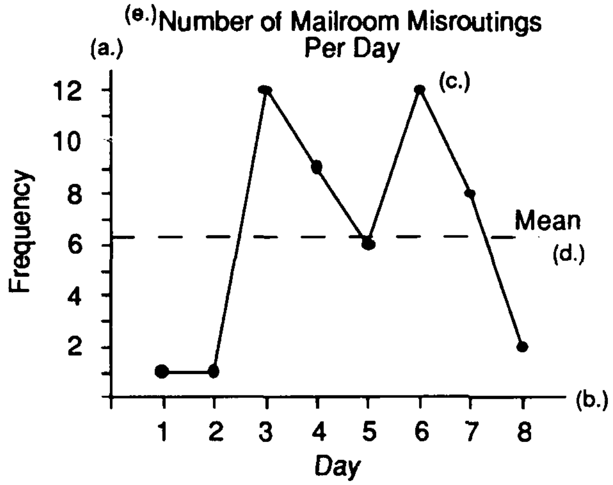
  - If you chose frequency as your measuure, the mean = 51/8 = 6.38

  - If you chose relative frequency as your measure, the mean = 100%/8 = 12.5%. Note that the mean of the frequency, 6.38, is 12.5% of the sum of measures,51. That is (6.38/51)*100% = 12.5%.

- The mean is not always included on a run chart. It may be useful to calculate it so that you can determine how the process varies around a line of central tendency.

Constructing a Run Chart

Step 4 Construct the Chart



a. Mark and label the vertical scale (measurements)

b. Mark and label the horizontal scale (time)

c. Plot the points and connect

d. Draw in the mean

e. Label the chart

Checking and Acting: Control Charts and Run Charts

- First, examine the range of measurement values. In our example, we will use the frequency measure. The values range from 1 to 12.
  - Mark off the approximate scale to accommodate the range.
  - Label the vertical axis, in our example, "Frequency."
- Next, determine the number of measures in the time scale. In our example, we recorded 8 days.
  - Mark off the approximate scale to accommodate the range.
  - Label the horizontal axis, in our example, "Day."
- The third step, c, is to plot the points. Use a point to mark the intersection of the frequency for each day. Connect the points.
- Next, plot the mean as a straight horizontal line through the data. Recall that the mean = 6.38.

- The final step is to label the run chart. Choose a label that identifies the context of the data. In our example, we chose, "Number of Mailroom Misroutings Per Day."

Interpreting Run Charts

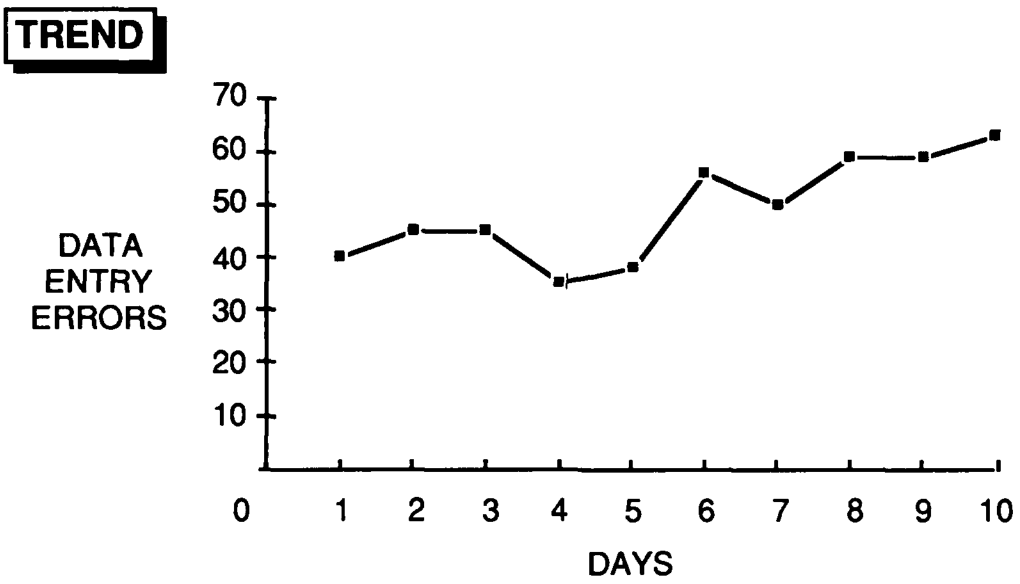
RUN CHART PATTERNS

- Trend
- Shift in Level
- Cyclical Pattern
- Bunching
- Two Groups, Shift in Level
- Interaction Between Groups

Checking and Acting: Control Charts and Run Charts

- Run charts are useful management tools because they graphically depict trends and patterns over time.
- Familiarity with the processes you control will allow you to detect the reasons for run chart patterns and take corrective action.
- The above patterns may appear in run charts.
- Interpreting a pattern requires knowledge of the process.
- There can be more than one contributing factor causing the pattern.

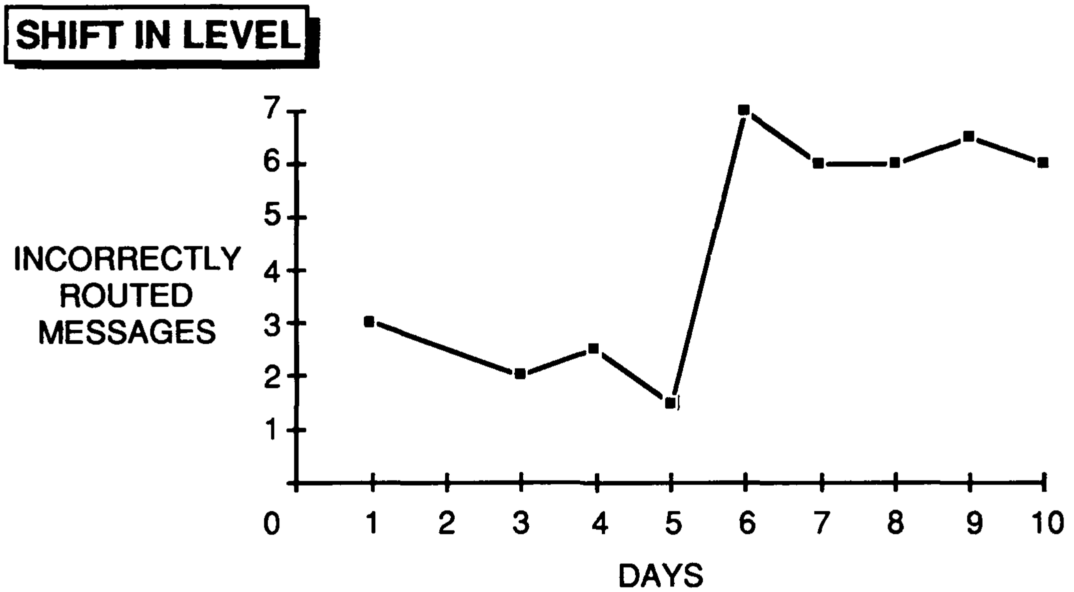
Interpreting Run Charts



Checking and Acting: Control Charts and Run Charts

- This run chart represents the number of data entry errors made per day in a large data entry pcol.
- A trend is a gradual rise or fall of points, usually six or seven points in a row. A trend indicates that the process is drifting.
- A reason for the trend starting at day four might be an unforeseen increase in workload resulting in more errors due to both more processing and personnel fatigue due to the heavy workload.
- The trend may also be due to poor operators who are drifting back into poor data entry techniques, or equipment which is slowly coming out of adjustment.

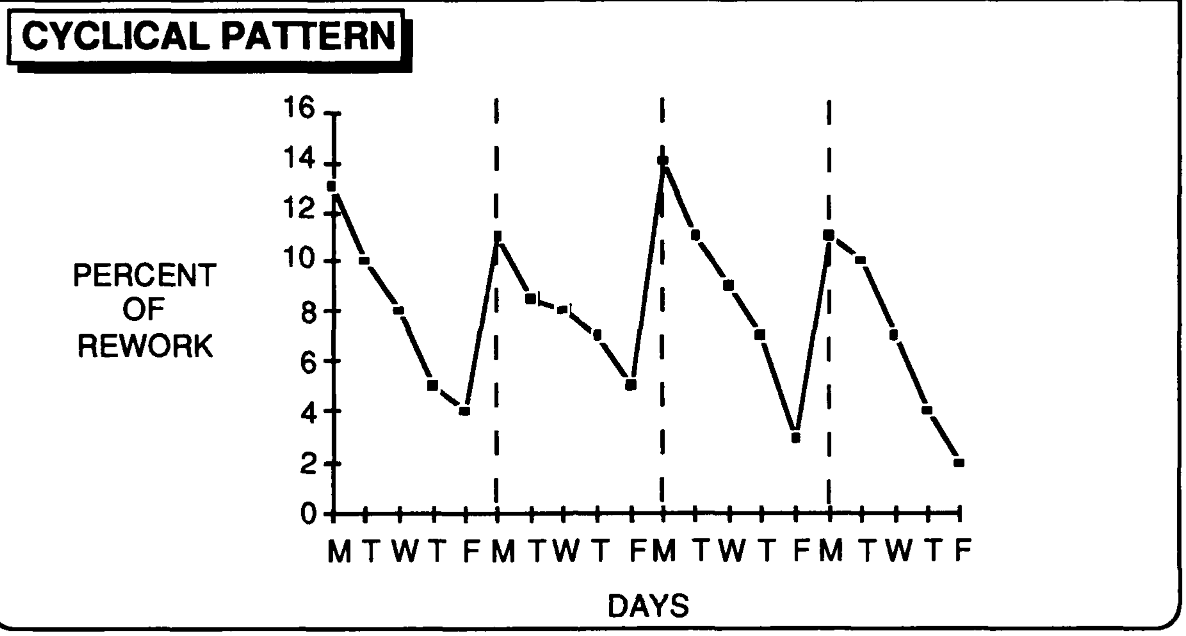
Interpreting Run Charts



Checking and Acting: Control Charts and Run Charts

- This run chart shows the number of messages incorrectly routed per day in a DoD communications function.
- The pattern shown is a *sudden shift in level.* Shifts indicate that something which has strong influence on the process has been changed so that the process moves from one level to another.
- One interpretation of the pattern could be that new and inexperienced personnel were put on duty on day five.
- Other reasons for the sudden shift may include a breakdown in equipment, breakdown in techniques being taught, or a different management policy.

Interpreting Run Charts

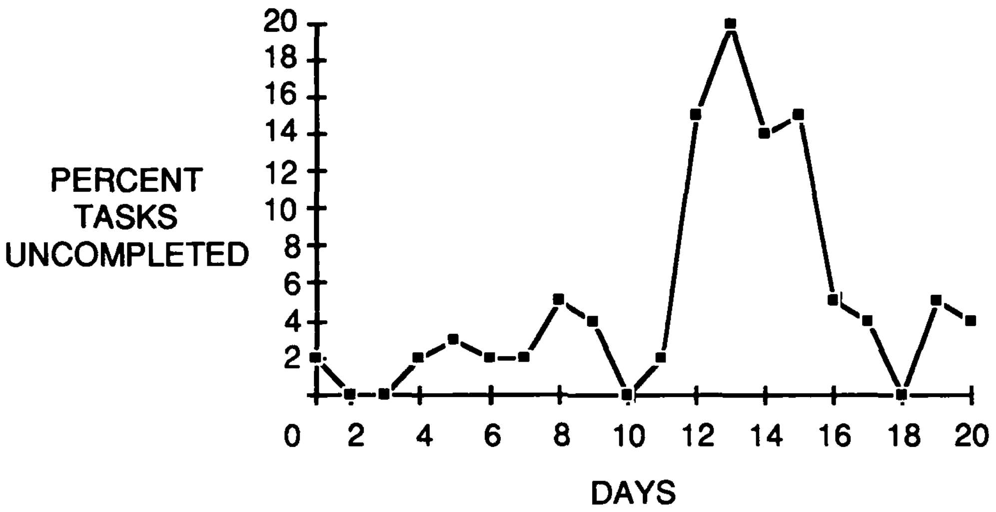


Checking and Acting: Control Charts and Run Charts

- This chart shows the percent of rework per day for a real property maintenance function.
- It is an example of a *cyclical pattern*, a consistent pattern of repeated high and low points that recurs periodically.
- There can be many reasons for this pattern. You should consider:
  - Personnel (manpower)
  - Environment or machines
  - Methods
  - Material.
- Note that the pattern may be related to the days of the week.

Interpreting Run Charts

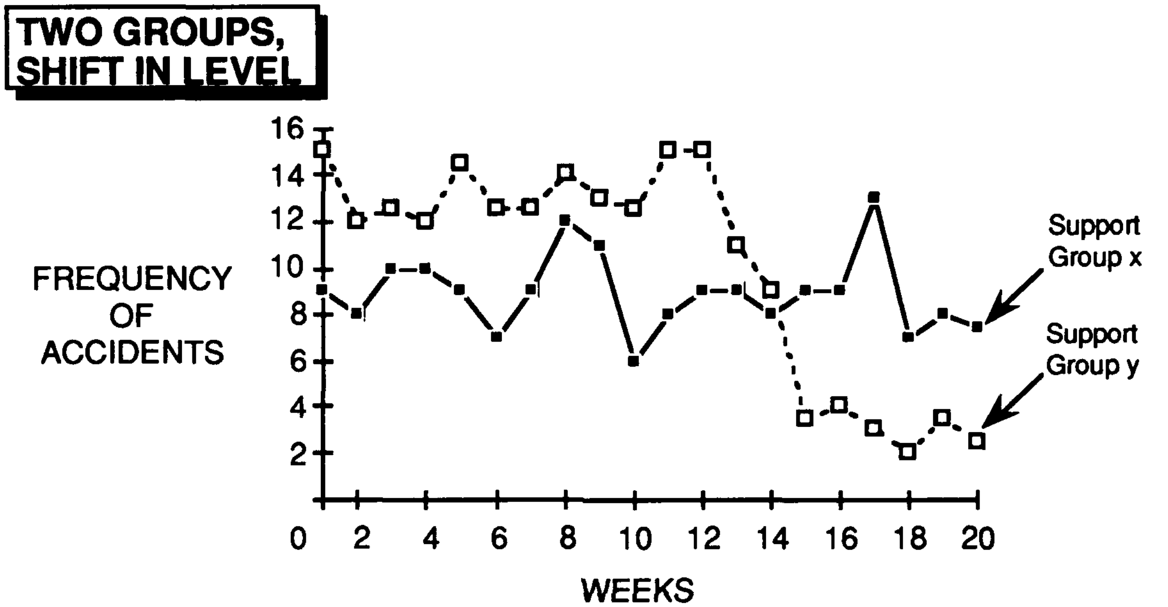
BUNCHING



Checking and Acting: Control Charts and Run Charts

- This run chart shows the percent of tasks uncompleted in a contracting shop over a 20 day period.
- It is an example of *bunching* and indicates that a special event has occurred for a short period of time. The process itself has not shifted, it came back down to its original level.
- One interpretation might be that liberal leave was granted during the time period in which the bunching occurred. Therefore, work that normally would have been completed was left unfinished.
- Another reason might be that some of the equipment needed to complete the work was scheduled for maintenance between days 10 and 18.

Interpreting Run Charts

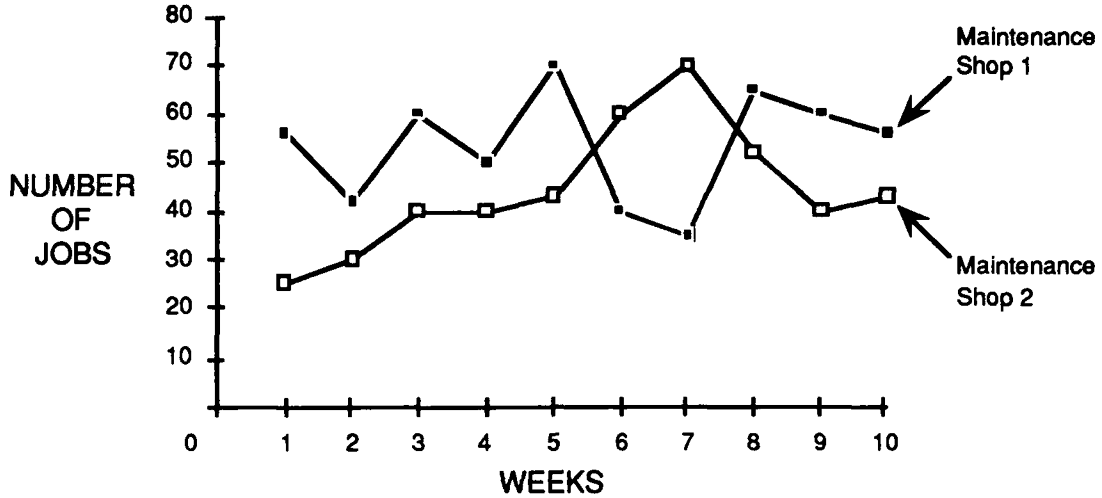


Checking and Acting: Control Charts and Run Charts

- This *comparison of two groups* illustrates *a sudden shift in level.*
- It is important that the two groups be as similar as possible when making comparisons.
- This comparison shows the frequency of accidents between two military base support organizations of similar size and function. You would not want to compare the accident frequency between a personnel shop and a squadron of pilots.
- Note the sudden shift in level in Support Group y. One of the reasons for the sudden drop in accidents might be that its supervisors initiated a safety program. Thus, this chart also <u>shows the results of corrective action</u> of one group in comparison to another control group.

Interpreting Run Charts

INTERACTION BETWEEN GROUPS



Checking and Acting: Control Charts and Run Charts

- This run chart shows *an interaction between two groups.*
- Interactions occur when the lines representing two or more samples cross each other.
- Again, it is important to compare similar groups which can interact. I could pick dissimilar and unrelated functions, such as a contracting office and a DoD health care agency, and "compare" similar measures for them. The lines might cross, but chances are that the "interaction" shown would be completely meaningless.
- If this example depicts two maintenance shops which performed the same function at the same location, the interaction might indicate that Maintenance Shop 2 took over Maintenance Shop 1's work between days 5 and 8.

Exercise 6-1

BUILDING A RUN CHART

Exercise 6-1: Building a Run Chart

Scenario:

- Suppose that you are the manager of a large procurement division. You've just learned about run charts and you've decided to track the daily errors made in documentation in your division for 15 day periods. You decide to do this for three consecutive 15 day periods.
- The data you obtain for the errors made in the first fifteen days is as follows:

  12, 8, 17, 14, 10, 13, 7, 10, 9, 7, 16, 11, 8, 8, 12

Task:

- Construct a run chart for the first fifteen days.
  - First, construct the chart using frequency measures.
  - Then, construct it using relative frequency measures.

Discussion Questions:

- What is the advantage of using frequency measures? Relative frequency measures?
- Did you detect any patterns?

Final Tips and Reminders

Danger!

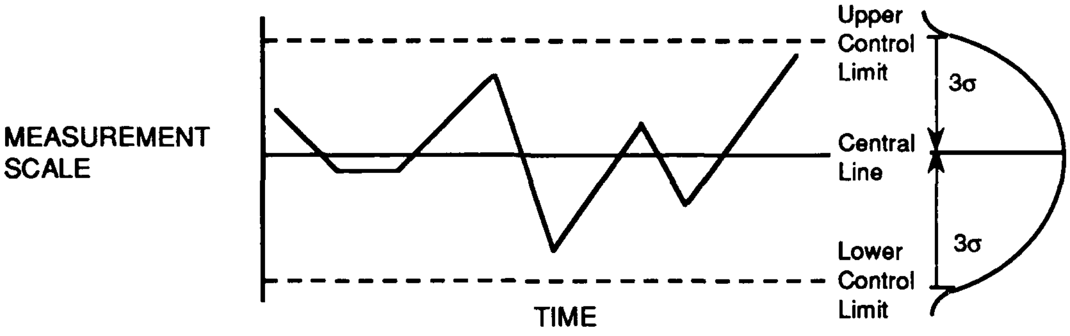
- There is a tendency to see every variation as important.
- Run charts should be used to *focus* attention on truly *vital changes.*

Checking and Acting: Control Charts and Run Charts

CONTROL CHARTS

What Is A Control Chart?

A Control Chart is a run chart with **statistically** determined upper (Upper Control Limit) and lower (Lower Control Limit) lines drawn on either side of the central line.



Checking and Acting: Control Charts and Run Charts

- The control limits are used as a basis for judging the *significance of variation.* They are calculated from process data and should not be confused with specification limits.

- Notice the normal distribution we've drawn on its side at the end of the control chart. The upper and lower limits of the control chart are constructed from the *normal distribution* by taking three standard deviations from either side of the mean of the data.

Why Use a Control Chart?

Judgment

- Determine if process in statistical control
- Distinguish special and common causes

Operation

- Achieve and maintain statistical control

Checking and Acting: Control Charts and Run Charts

- Dr. Walter Shewhart (of Shewhart Cycle of Learning fame) first made the distinction between controlled and uncontrolled variation, due to what is called common and special causes. (We will review these terms later in the section). He developed the control chart to distinguish between special and common causes.

- Several types of control charts have been developed to analyze variables (quantitative data) and attributes (qualitative data). All control charts have two basic uses. In Shewhart's terms, the uses of control charts are:

  - As a *judgment*, to determine if a process is operating in statistical control, and to signal the presence of special causes of variation so that corrective action can be taken.

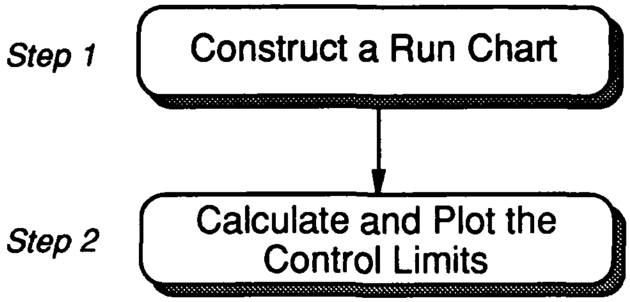
  - As an *operation*, to achieve and maintain the state of statistical control, by extending the control limits as a basis for the real-time decisions.

Checking and Acting: Control Charts and Run Charts

- Control charts are commonly used in the Check phase of the PDCA cycle to analyze data.

Source: *Continuing Process Control and Process Capability Improvements*, Ford Motor Company, September, 1985.

Constructing a Control Chart



Checking and Acting: Control Charts and Run Charts

- *Step 1: Construct a Run Chart.* First, construct a run chart using the steps learned in the previous section.

- *Step 2: Calculate and Plot the Control limits.*

  - First, calculate the *population standard deviation.* Recall the population standard deviation formula, as shown below.

$$\sigma = \sqrt{\frac{\sum (x - \mu)^2}{n}}$$

x = value of a particular data point

$\mu = \frac{\sum x}{n}$ = mean (average) of data points

n = number of data points

- Next, calculate the upper control limit (UCL) = mean + 3 * population standard deviation

- Next, calculate the lower control limit (LCL) = mean - 3 * population standard deviation.

- Finally, plot the UCL and LCL on the run chart as straight lines.

• There are many different types of control charts. Each requires a unique way to calculate the measure of central tendency and control limits. For our purposes, using the mean and three sigma (three standard deviations) away from the mean will provide sufficient information.

Exercise 6-2

CONSTRUCTING A CONTROL CHART

Exercise 6-2: Constructing a Control Chart

Scenario: Consider the scenario and data in Exercise 6-1: Building a Run Chart.

Task: Using your run chart of procurement documentation errors, construct a control chart.

Process Control

- Variation: Common and Special Causes
- Process Control and Process Capability
- Process Control and Improvement Cycle
- Managerial Action

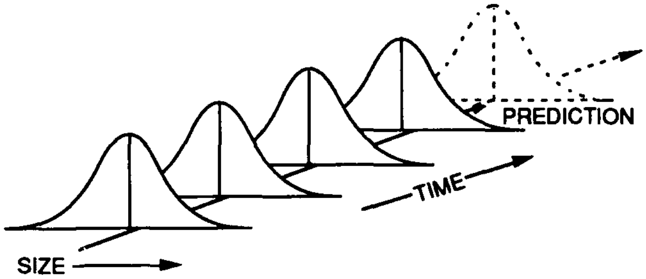
Checking and Acting: Control Charts and Run Charts

- As discussed previously, control charting is used in the continuous improvement process to:
  - Determine if a process is in statistical control
  - Achieve and maintain statistical control.
- Before discussing how to use control charting in the continuous improvement process, we will review the concepts of special and common variation, and process control and capability. Then, we will discuss the three step process improvement cycle.
- Finally, we will discuss managerial action, including common mistakes, in the process improvement cycle.

Variation: Common and Special Causes

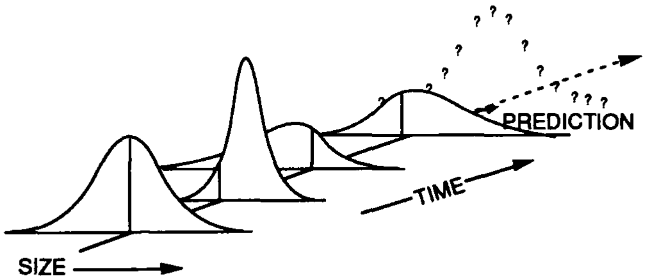
Common Causes:

Output of process forms a distribution that is stable over time and predictable.



Special Causes:

The process output is not stable over time and is not predictable.



Checking and Acting: Control Charts and Run Charts

- No two products or services are alike because any process contains variation. For example, the time required to process an invoice could vary according to the people involved, the reliability of the equipment used, the accuracy and legibility of the invoice, the procedures used, and the volume of other work in the office.

- To manage a process and reduce variation, you must track variation back to the source. The first step is to make a distinction between common and special causes of variation.

- *Common causes* are the many sources of variation that occur in a process due to randomness or pure chance. While individual measured values are all different, they tend to form a pattern then can be described as a distribution. An example of a common cause might be that a good typist will, on the average make a number of typing errors. The typist can control making errors, but not eliminate them because they are random. Unless all the special causes of variation are identified and corrected, they will continue to affect the process output in unpredictable ways.

- *Special causes* are factors that are considered unusual and that can be eliminated. These factors are not random and cannot be described by a distribution. An example of a special cause would be a good typist suddenly making many errors because of a malfunctioning machine. If the machine is repaired the typist will return to her normal low rate of errors. Special causes can be eliminated.

- Unless all the special causes are identified and connected, they will continue to affect the process output in unpredictable ways.

Variation: Common and Special Causes

Special Cause ⟹ *Local Actions*

- Usually taken by people close to the process
- Can correct about 15% of process problems

Common Cause ⟹ *Actions on the System*

- Usually requires management action for correction
- Are needed to correct about 85% of process problems

Checking and Acting: Control Charts and Run Charts

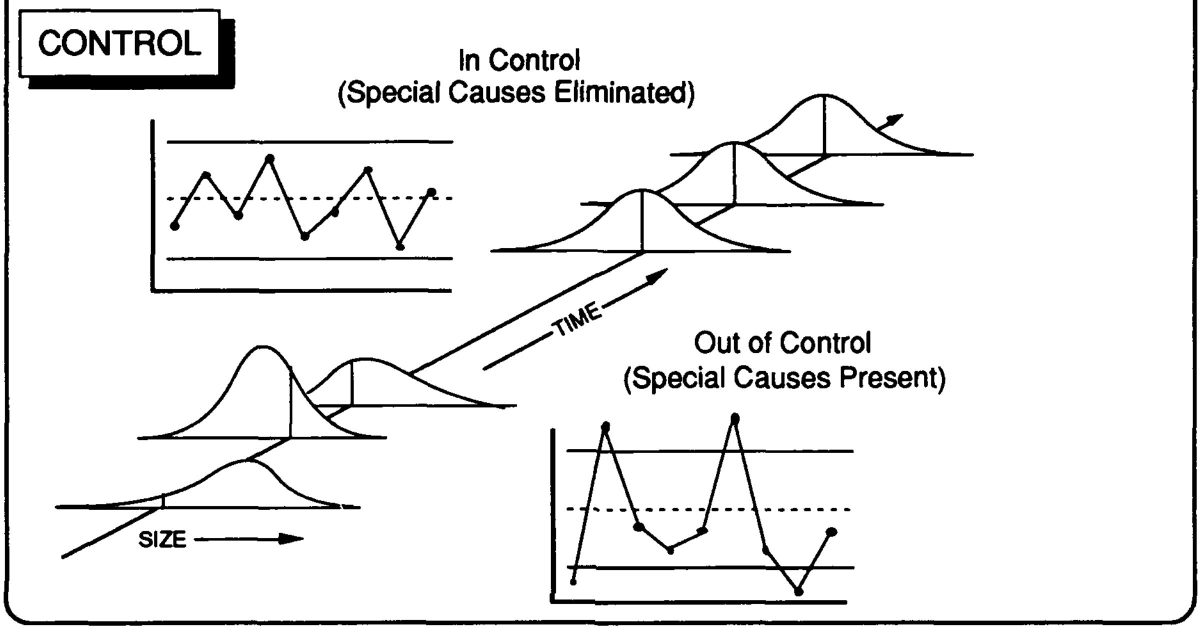
- Common and special causes of variation each require different types of action to reduce them.

- *Special Causes* of variation can be detected by the control chart (as will be discussed later). They are not common to all the operations involved. The detection and removal of special causes is usually the responsibility of someone directly involved with the process. Resolution usually requires *local action.*

- *Common Causes* can be indicated by the control chart, but the causes themselves are more difficult to isolate. The people involved with the problem can usually best identify common causes, but the resolution is the responsibility of management. Resolution usually require *actions on the system.*

- It is important to distinguish between special and common causes, in order to correctly identify the type of action required. For example, it could be very costly to the organization to take local action (e.g. adjusting a machine) when management action is required (e.g., selecting supplier that provides consistent input materials).

Process Control and Capability

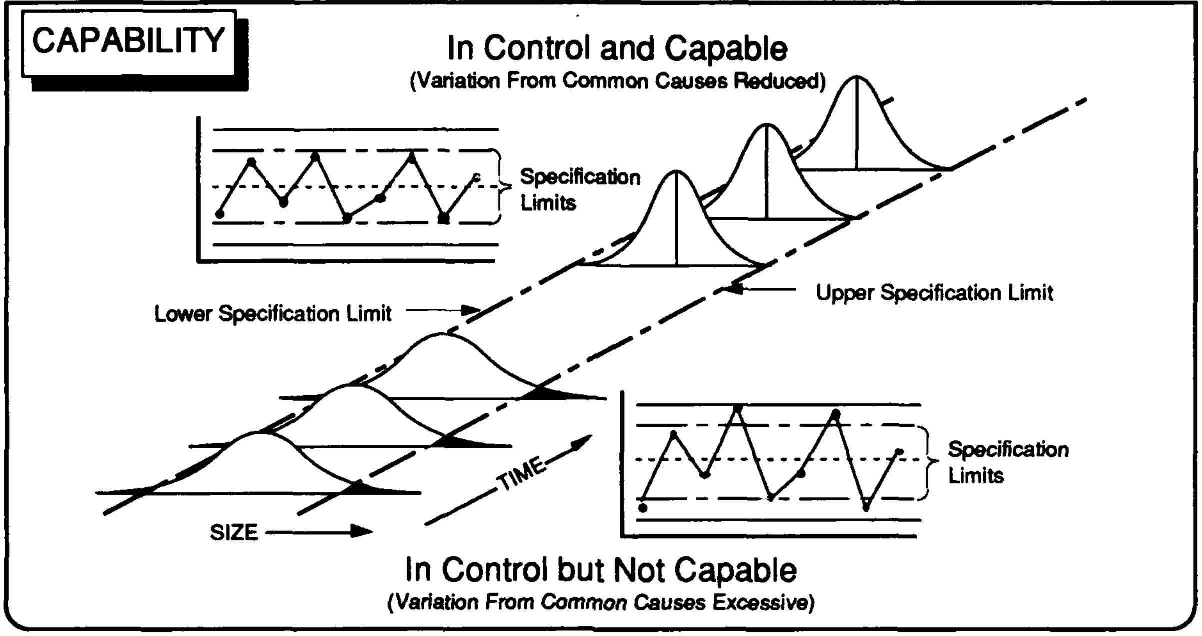


Checking and Acting: Control Charts and Run Charts

- A process is in *statistical control* when the only sources of variation are common causes. Recall that control charts are used to signal special causes of variation, so that the approximate action can be taken to eliminate them.
- A process in control is *stable* over time and *predictable*. After eliminating special causes and bringing a process under control, you may then assess its capability to meet customer needs.
- Consider the typing example. You track the number of errors in memos and find that the process consistently produces between two and eight errors per memo. You may want between zero and five errors, but the process is in control because the output is stable and predictable over time.

Source: Continuing Process Control Capability Improvement, Ford Motor Company, September 1985.

Process Control and Process Cability



Checking and Acting: Control Charts and Run Charts

- *Process capability* is determined by the total variation that comes from common causes. It is the best statistical performance that can be reached after all special causes have been eliminated and represents the best performance of the process itself.

- If the typist has the machine repaired, then a special cause for errors has been eliminated. She or he can control random errors through diligence. Statistically, errors will still be made because they are random (common cause), and the average errors made by the typist over time represent the best that can be done - i.e., the process capability is the best that can be accomplished.

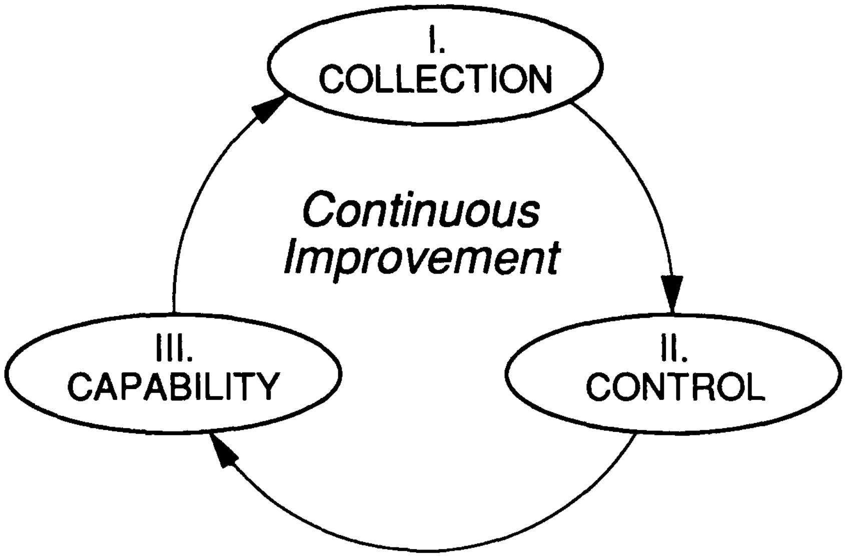
- Process capability is often thought of in terms of the proportion of output that will be within the customer specification limits.

- Management action is required to reduce the variation from common causes and increase the process' ability to consistently meet specifications.

- Note that specification limits differ from control limits. Control limits are calculated based on the variation within the process, while specification limits are based on customer needs. Therefore, a process can be in control and still not meet customer needs.

Source: Continuing Process Control Capability Improvement, Ford Motor Company, September 1985.

Process Control and Improvement Cycle



Checking and Acting: Control Charts and Run Charts

Process improvement using control charts is an iterative process of data collection, process control, and process capability.

- *Collection.* The steps in the data collection phase include:
  - Run the process
  - Collect the data
  - Plot the data on a graph.
- *Control.* The steps in the process control phase include:
  - Calculate trial control limits based on the data from the output of the process.
  - Draw the limits on the chart as a guide to analysis. Remember that the control limits are reflections of the natural variability of the process, and are not specifications limits.
  - Compare the data to the control limits to determine if the process is in control.

  - If there are special causes, study the process to determine the source and eliminate special causes.

  - After taking local action to eliminate special causes, collect further data and recalculate control limits.

- *Capability.* The steps in the process capability phase include:

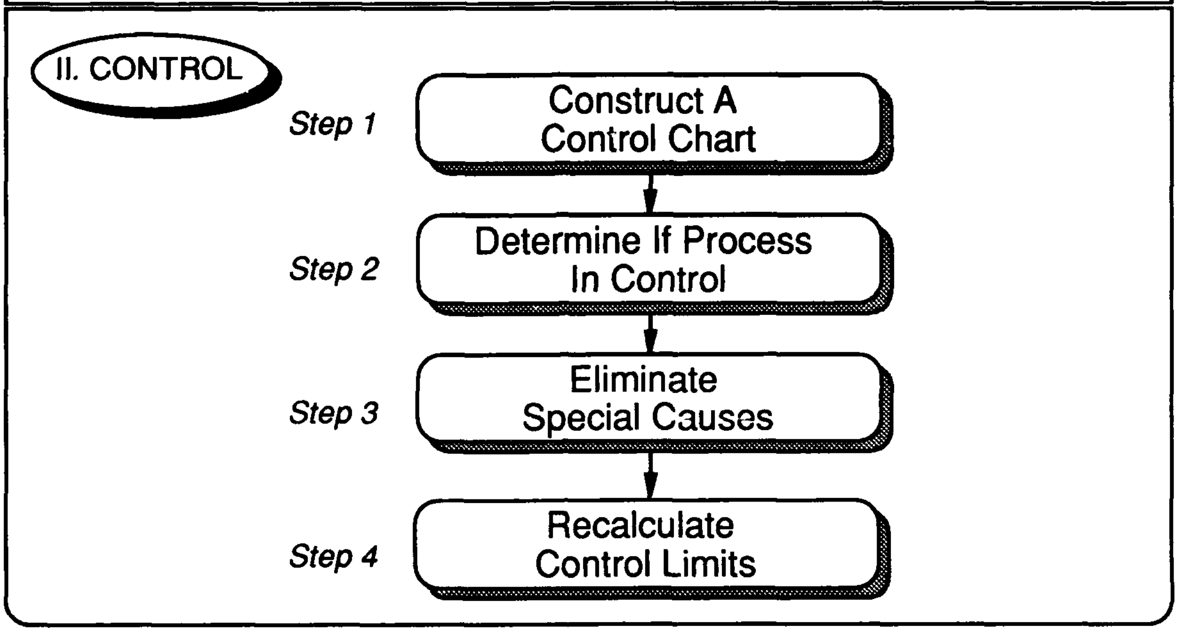
  - Assess process capability after all special causes have been eliminated and process is in control.

  - If variation from common causes is excessive and the process cannot consistently produce within customer requirements, investigate the process.

  - If necessary, take management action to reduce common variation and improve the system.

- For *continuous process improvement*, gather more data, work to reduce process variation by operating the process in control and continually improving process capability.

Process Control and Improvement Cycle

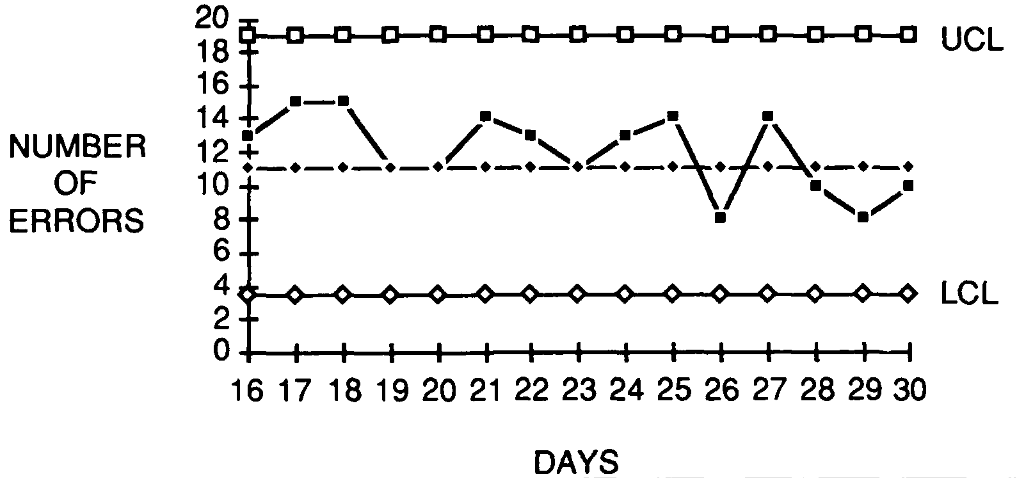


Checking and Acting: Control Charts and Run Charts

- There is a four step process to establish and maintain process control as shown above. Each is described in the following pages.

Process Control and Improvement Cycle

II. CONTROL *Step 1* Construct A Control Chart



Checking and Acting: Control Charts and Run Charts

- To demonstrate a process which is in control, we will use the example of tracking errors in procurement documentation. (You used this scenario to construct a run chart and control chart.)

- The control chart above represents the second 15 day period in your experiment to determine whether the process you follow in making procurements is under control.

- The chart was constructed by plotting the points for the second 15 day period, that is, making a run chart.

- But it is important to note that the UCL, LCL, and mean were calculated using all 30 days worth of data you have collected so far. Why? Because the larger the sample size, the more the values you calculate for the mean and population standard deviation will represent the true population mean and standard deviation.

Process Control and Improvement Cycle

II. CONTROL

Step 2 Determine if Process is In Control

IN CONTROL

- Most of the points are near the center line.
- A few of the points spread out and approach the control limits.
- None of the points exceed the control limits.
- There are no patterns (trends, cycles, etc.).

OUT OF CONTROL

- Absence of points near the center line.
- Too many points near the control limits.
- Presence of points outside the control limits.
- Patterns are present.

Checking and Acting: Control Charts and Run Charts

- The next step is to determine whether the process is in control.

- A process *in control* has the following characteristics:

  - Most of the points are near the center line.
  - A few of the points spread out and approach the control limits.
  - None of the points exceed the control limits.
  - There are no patterns (trends, cycles, etc.).

- A process *out of control* has the following characteristics:

  - Absence of points near the center line.
  - Too many points near the control limits.
  - Presence of points outside the control limits.
  - Patterns are present.

- Your control chart has the characteristics of a process in control. So does your chart for the first 15 days if you look back at it.

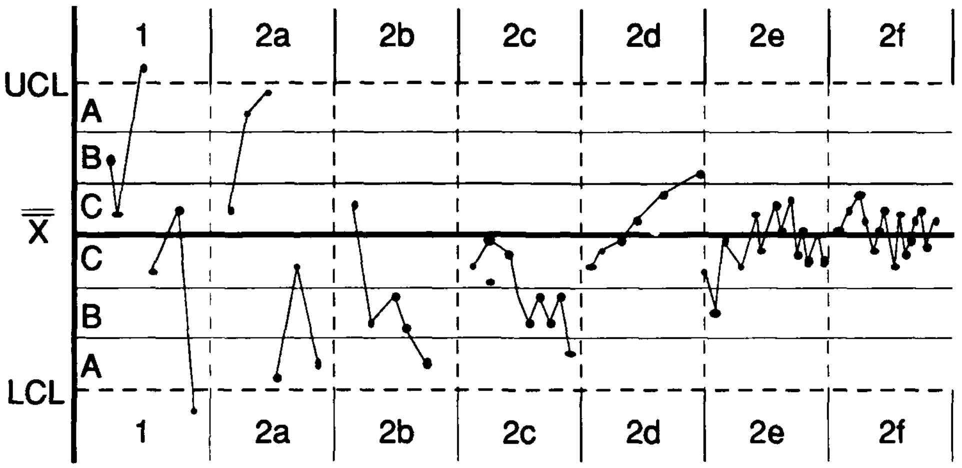
- Remember that for three sigma quality, three out of 1000 points will be outside the control limits. One point outside the limits may not indicate an out of control process, but you may want to investigate the cause. Multiple points outside the control limits, especially in a small sample, indicate a system out of control.

Process Control and Improvement Cycle

II. CONTROL

Step 2

Determine if Process in Control



Checking and Acting: Control Charts and Run Charts

- The previous page provided general rules to determine control. The chart above may be used to test control according to the rules listed below.

- Generally speaking, the process is said to be "out of control" if:

1. One or more points fall outside of the control limits

or

2. One of the "out of control" conditions exists, as defined by the chart above and the rules below.

2a. Two points out of three successive points are on the same side of the center line in Zone A.

2b. Four points out of five successive points are on the same side of the center line in Zone B or beyond.

2c. Nine successive points fall on one side of the center line.

2d. Six or seven consecutive points increase or decrease (trend).

2e. Fourteen consecutive points alternate up and down.

2f. Fifteen consecutive points within Zone C (above and below center line).

Source: The Memory Jogger: A Pocket Guide of Tools For Continuous Improvement, GOAL, 1985.

Process Control and Improvement Cycle

II. CONTROL

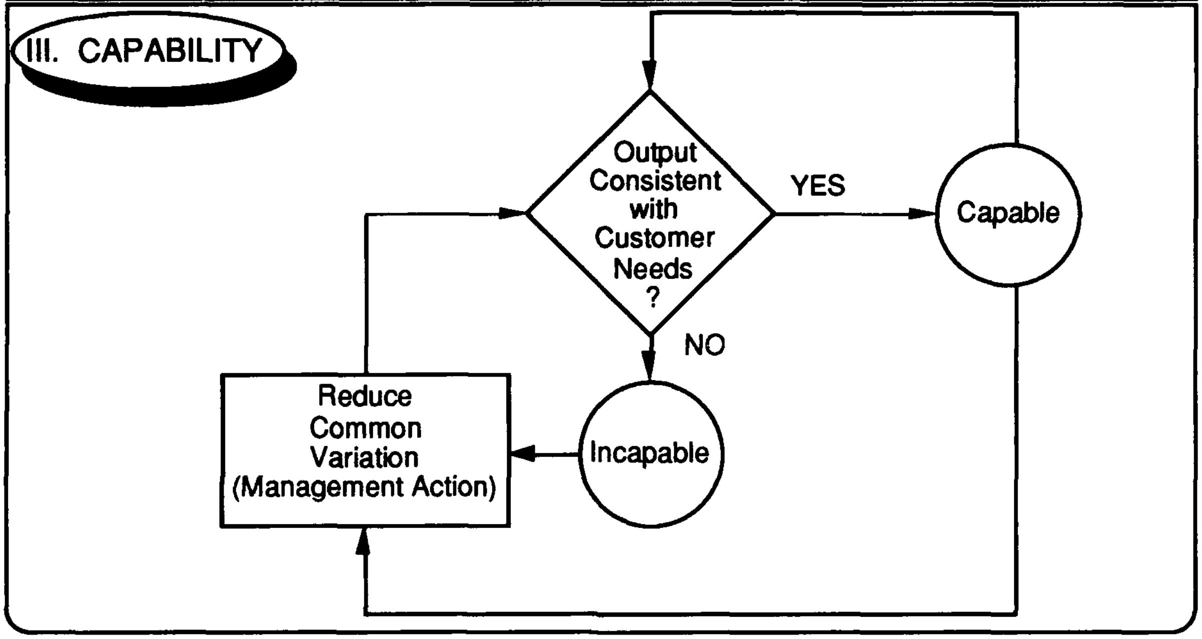
STEP 3 Eliminate Special Causes → STEP 4 Recalculate Control Limits

STEP 3: Eliminate Special Causes	STEP 4: Recalculate Control Limits
• Double check calculations for points in question.	• Throw out points outside control limits.
• Determine source(s) of special cause(s).	• Recalculate mean and control limits using entire data set.
• Eliminate special causes.	• Chart data.

Checking and Acting: Control Charts and Run Charts

- *Eliminate Special Causes.* Patterns and points outside the control limits indicate *special causes.* They show that something is happening to your process which is not random or statistical in nature.
  - The first step is to make sure the calculations for the point(s) in question are correct. If so, the points indicate a special cause.
  - The next step is to find what the special cause(s) is and eliminate it.
- *Recalculate Control Limits.* The last step to be taken, *after you have eliminated special causes*, is to re-calculate the mean and control limits after throwing out the points that were outside the control limits.
- Another important point is that, as a rule of thumb, it is not unusual to find that variation grows by up to one-third over the long run due to factors such as deterioration of equipment, changes in personnel, or changes in environment. Therefore, it is necessary to keep watching your process even though it is presently in control.

Process Control and Improvement Cycle



Checking and Acting: Control Charts and Run Charts

- The final step is to determine process capability based on customer needs. The process may be in control and producing consistently, but it may be consistently unable to meet customer needs.

- If the process is not consistently producing within customer limits, it is management's responsibility to reduce common variation and improve process output.

- In the TQM spirit of continuous improvement, management must continually evaluate process control and capability to reduce variation and ensure conformance to customer requirements.

Exercise 6-3

CONSTRUCTING A CONTROL CHART TO DETERMINE PROCESS CONTROL

Exercise 6-3: Constructing a Control Chart to Determine Process Control

Scenario: Consider the Procurement Office Control Chart which plots the number of errors against days. Consider the following data sets:

- Data for the first 15 days: 12, 8, 17, 14, 10, 13, 7, 10, 9, 7, 16, 11, 8, 8, 12.
- Data for the second 15 days: 13, 15, 15, 11, 11, 14, 13, 11, 13, 14, 8, 14, 10, 8, 10.
- Data for the third 15 days: 6, 13, 14, 12, 14, 13, 25, 26, 7, 15, 15, 11, 7, 13, 12.

Task:

- Use the process control and improvement cycle to determine if the process is in control and capable. Recall that you constructed a control chart for the first 15 days in Exercise 6-2, and the control chart for the second 15 days is shown on page 6-39.
  - First chart the third 15 day set. Is the process in control?
  - Then chart the entire 45 days after special causes have been eliminated.

Discussion Questions:

1. Is the process in control?
2. Are there any special causes evident?
3. Is the process capable? (Assume you are the customer--would the process be producing within your specifications?)

Managerial Action

Eliminating Special Causes of Variation

- Use timely data
- Isolate special causes as soon as possible
- Avoid unnecessary changes
- Try to prevent recurrence

Checking and Acting: Control Charts and Run Charts

- Special causes indicate an unstable system.
- Do the best you can to get data which is timely so that special causes are signaled quickly.
- Immediately search for a cause when your control chart gives a signal that a special cause has occurred. What was different on that occasion from other occasions?
- Do not make unnecessary fundamental changes in the process. Instead, seek ways to change some higher level system to prevent that special cause from recurring.
- Remember, most special causes can be eliminated by local action.

Managerial Action

Eliminating Common Causes of Variation

- Communicate with personnel at all levels
- Keep measurement process manageable
- Use multiple analysis approaches
- Look for cause-and-effect relationships

Checking and Acting: Control Charts and Run Charts

- Common causes of variation usually can't be explained by looking at points which are obvious, such as the high and low point. These points are random and probably will not reveal anything.
- Special causes are easier to spot and correct, and often can be corrected "locally." To reduce common variation, fundamental changes in the system may be necessary.
- Management should initiate and lead the change effort to reduce common causes and improve the process.
- To improve a stable process:
  - Talk to lots of people including local employees, other managers, and staff from various functions. Look for theories, causes and solutions.
  - Don't bother your staff with measurement, or make the measurement process too difficult. Change the measurement process if it contributes to variation.

- Look at your data in different ways. Use Pareto analysis to identify and rank categories of problems, or disaggregate your data to compare performance of subprocesses.

- Design experiments to try and determine cause and effect relations.

Managerial Action

Some Common Mistakes

Overadjustment →
- Type I Error
- Deciding a cause is special when it is a common cause

Inaction →
- Type II Error
- Deciding a cause is common when the cause is special

Tampering →
- Making changes to the process without a statistical reason
- Increases dispersion of a process

Checking and Acting: Control Charts and Run Charts

- There are some typical mistakes people make in process control.

- *Overadjustment (Type I Error).* A Type I error results when you believe a variation or a mistake to be a special cause when, in fact, it is a common cause .

- *Inaction (Type II Error).* A Type II error results when you decide a variation or a mistake is part of the system and a common cause when, in fact, the cause was special. It is a mistake to let a special cause continue to exist and influence the process because you believe it to be a common cause.

- You cannot eliminate the risk of both Type I and II errors simultaneously, but you can use statistical methods to help reduce the net economic loss from the two types of mistakes.

- *Tampering.* Tampering, one of the most common mistakes made by managers and staff alike, is making changes to the system when there is no statistical reason for it.

- Managers often make changes to try to beat the system. It can be tempting to try to make an adjustment "because it will probably make me or the control chart look better."

- Tampering increases the dispersion of a process. We'll show you in the next exercise that, on the average, tampering, or tweaking, will increase the standard deviation by twice it's normal value. Don't try to beat or lead the system. Only make changes when needed.

Exercise 6-4

THE QUINCUNX EXERCISE & THE IMPACT OF VARIATION

Checking and Acting: Control Charts and Run Charts

- We've given you some suggestions about process control; but we've also given you some warnings about *tampering with or tweaking* the system. It is a common mistake to try to think that "giving the system a boost" will make a desired change.
- Changes made to a system in control take thought and consideration and very definite and positive management control.
- The purpose of the following exercise is to show you what can happen if you try to influence the system by tweaking or guessing, i.e., what happens if you make unjustified changes that have not been well researched and thought out.

Exercise 6-4: The Quincunx Exercise

Scenario:

- The Quincunx is a machine which demonstrates that a randomly dropped pattern of balls will result in a normal distribution.

- The purpose of the demonstration is to show you that, if you try to better the system by tampering, the results will be worse and not better. We will demonstrate this by using the following four rules for adjusting the Quincunx funnel:

1. *Negligence.* Leave funnel aimed at 50. Don't adjust.

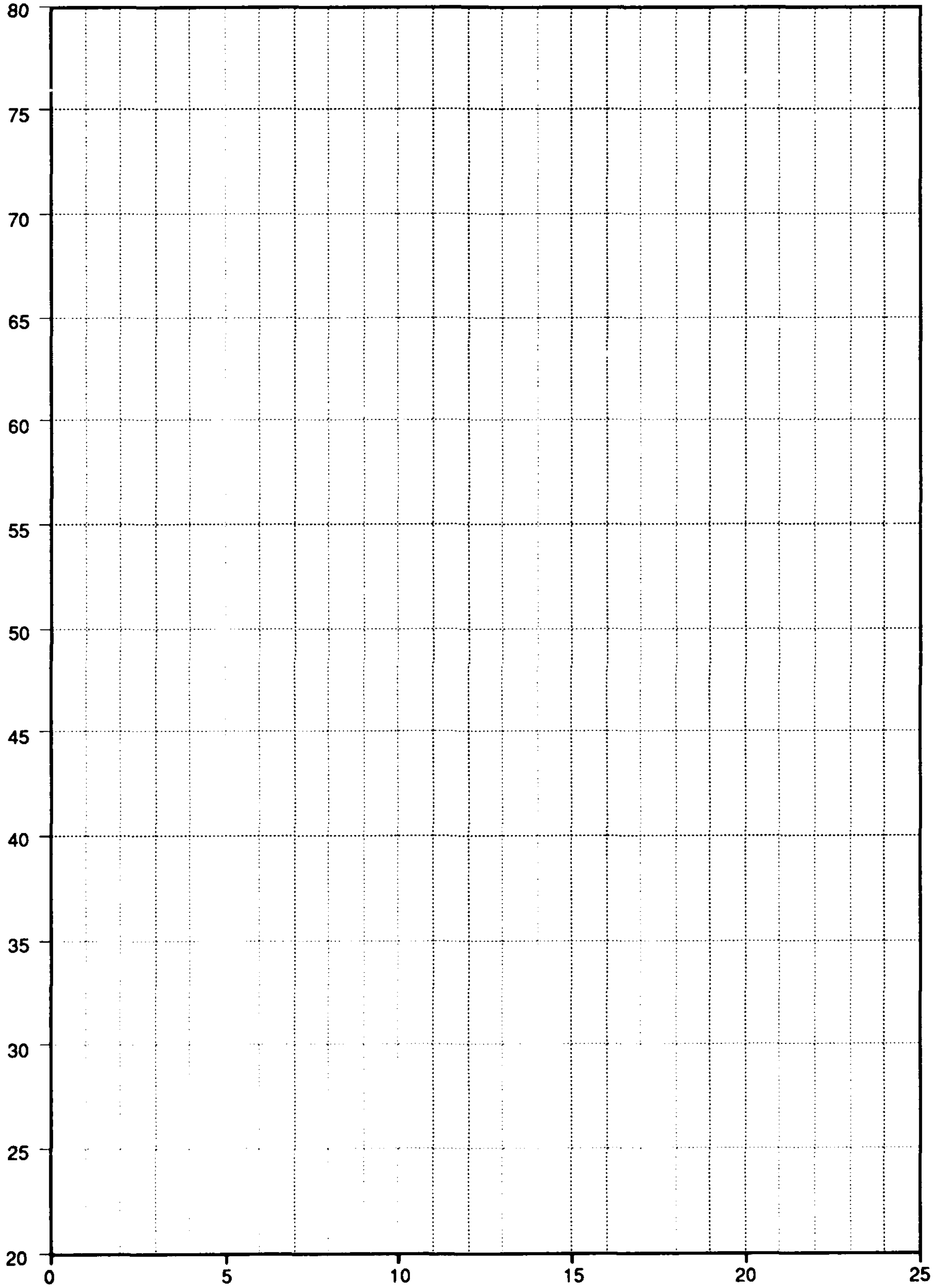
2. *Adjust from where you are.* Calculate the deviation from 50. Move the funnel from where it is to exactly compensate for the deviation.

3. *Adjust relative to target.* Calculate the deviation from 50. Set the funnel at 50 and move it to exactly compensate for the deviation.

4. *Match previous.* Set the funnel to make the next one just like the last one. (Aim the funnel at the location of the last bead.

Task:

- We will give each of you four blank run charts. Plot the positions of the first 10 to 25 balls. The results will graphically demonstrate tampering.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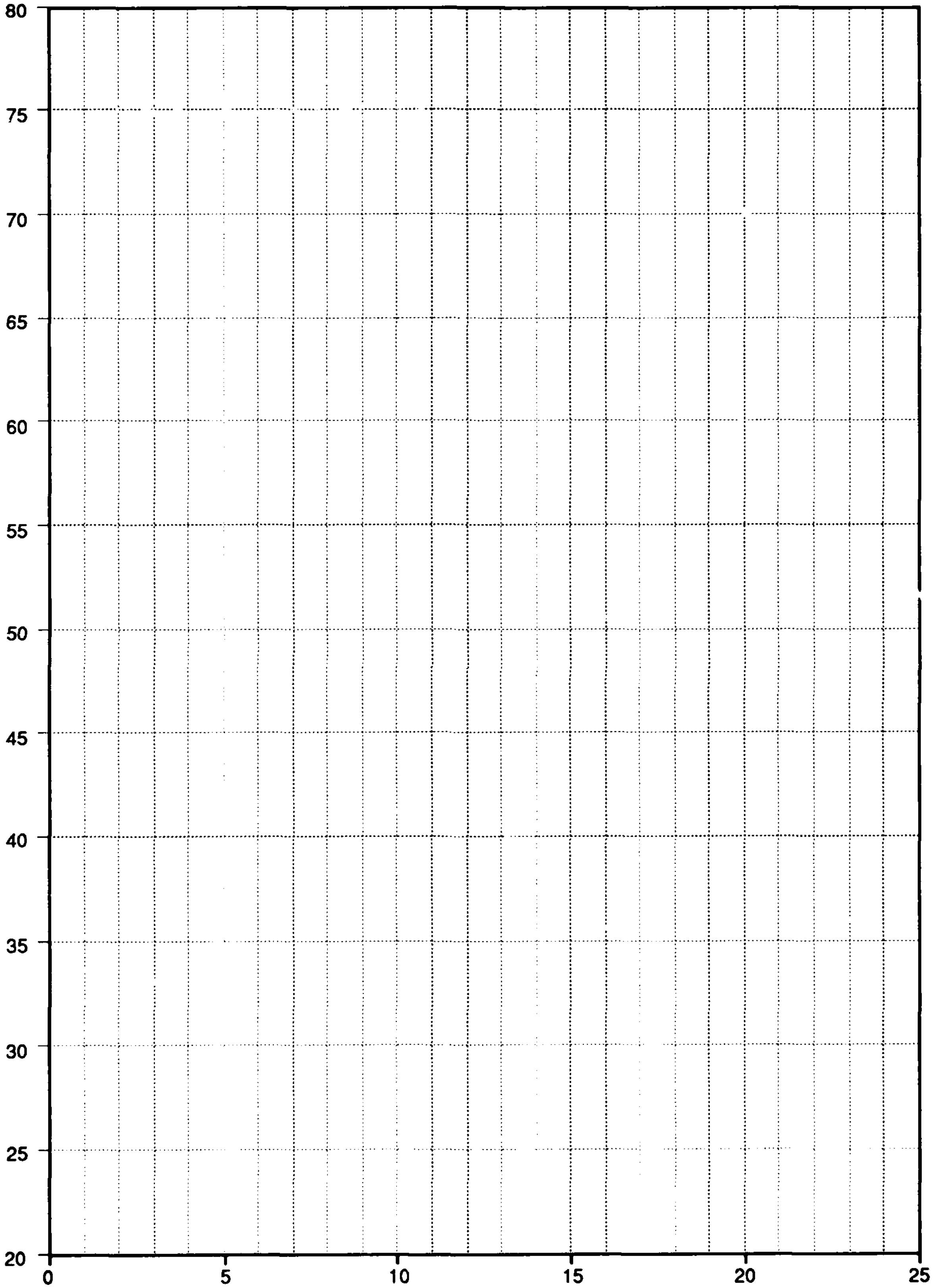
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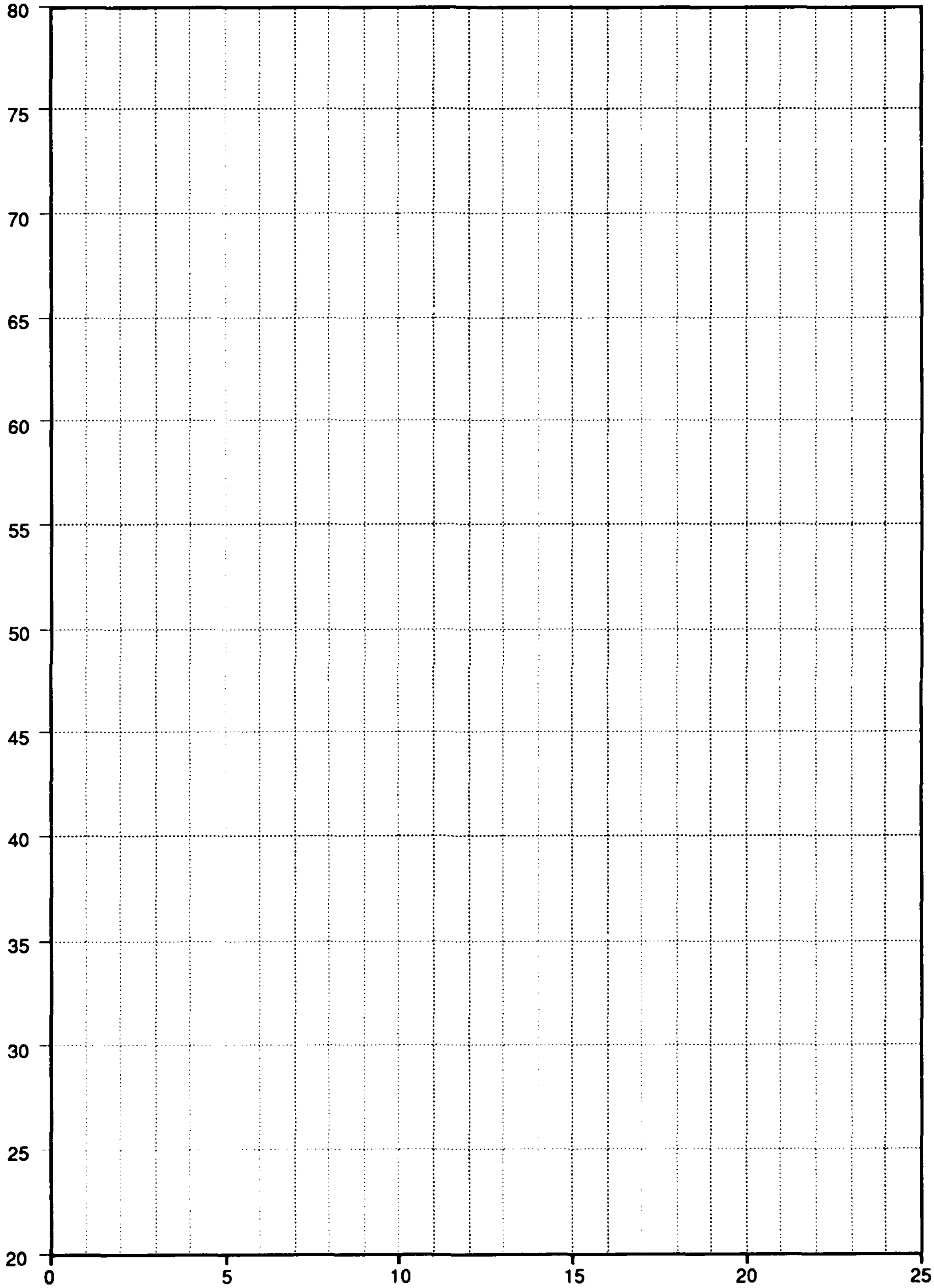
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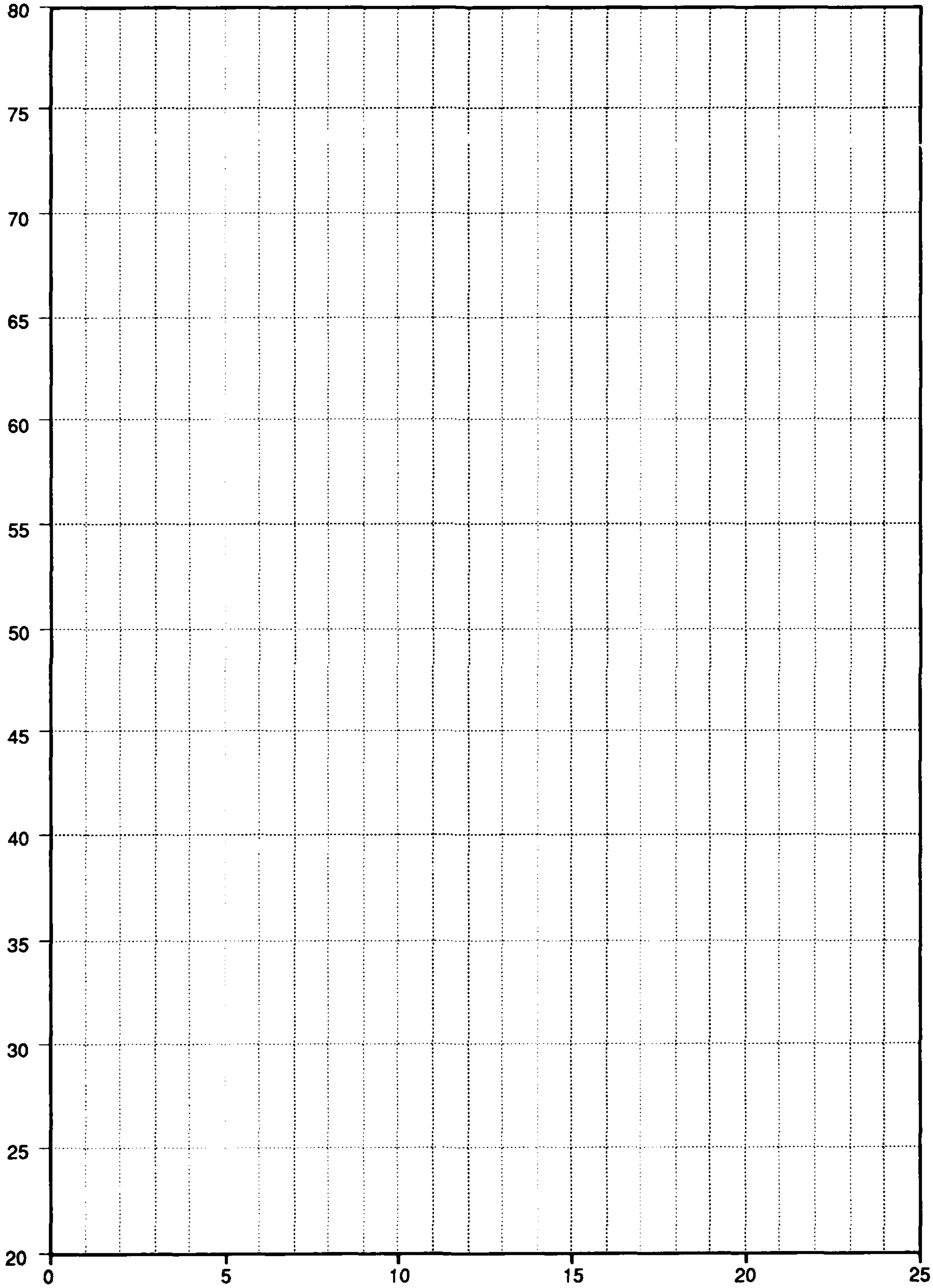
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Exercise 6-4: The Quincunx Exercise

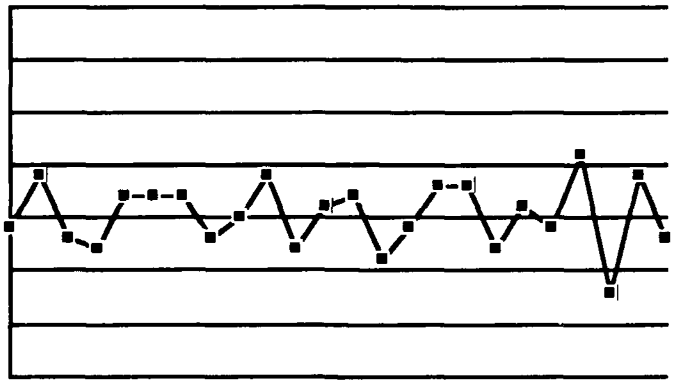
Rule 1
Sample Results

Checking and Acting: Control Charts and Run Charts

- This is an example of the type of pattern which could result using rule 1.

Exercise 6-4: The Quincunx Exercise

Rule 2
Sample Results

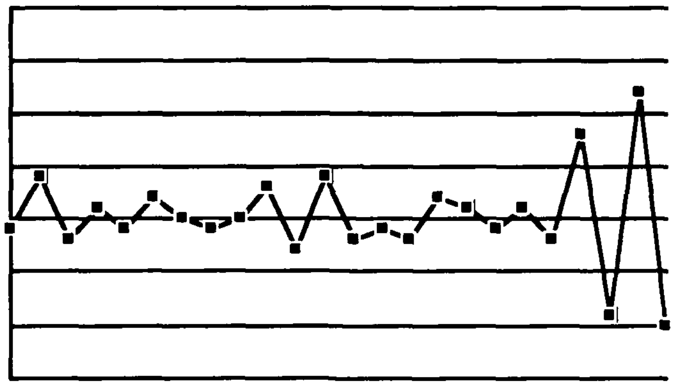


Checking and Acting: Control Charts and Run Charts

- This is an example of the type of pattern which could result using rule 2.

Exercise 6-4: The Quincunx Exercise

Rule 3
Sample Results

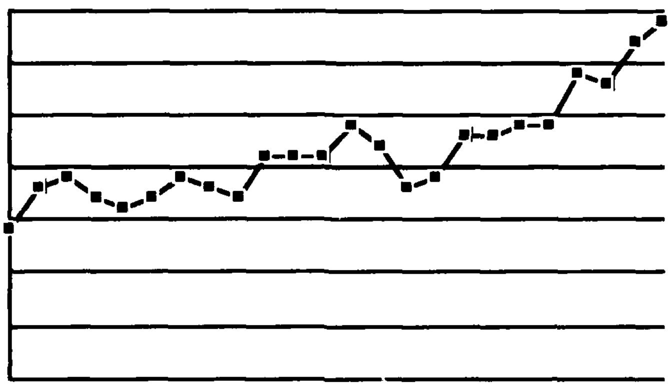


Checking and Acting: Control Charts and Run Charts

- This is an example of the type of pattern which could result using rule 3.

Exercise 6-4: The Quincunx Exercise

Rule 4
Sample Results



Checking and Acting: Control Charts and Run Charts

- This is an example of the type of pattern which could result using rule 4.

Exercise 6-4: The Quincunx Exercise

RESULTS FROM FUNNEL RULES

- Rule 1: Stable, miminal variance from target
- Rule 2: Stable, double the variance of rule 1
- Rule 3: Unstable, points wander in both directions
- Rule 4: Unstable, points wander in one direction

Checking and Acting: Control Charts and Run Charts

- Rule 1: Rule 1 will produce a stable distribution of points. It produces minimal variance from the target. Rule 1 represents a stable process, undisturbed by tampering.
- Rule 2: This rule produces stable output, but the expected variance of the distribution of points from the target will be double the expected variance under rule 1.
- Rule 3: The system will be unstable. The points will wander farther away in alternating directions from the target.
- Rule 4: The system will be unstable. Rule 4 will yield a random walk. That is, the points will wander farther away in one direction.

Exercise 6-4: The Quincunx Exercise

CONCLUSIONS

- Tweaking a stable process makes things worse
- Tweaking increases variation, risk and cost
- Adjusting a stable, well-targeted process is senseless tampering
- Statistical data will tell you when you should properly adjust a process

Checking and Acting: Control Charts and Run Charts

- If you have a stable, well-targeted process and you apply rules 2, 3, or 4, you are tampering (tweaking). You will make things worse instead of better.
- Tampering or tweaking a process means trying to compensate for or adjust the variation in the process. The results will inevitably increase the variation, your risks, and your costs.
- If you make an adjustment to a work process, a measurement or press your managers for reasons for variation, you are taking proper action if the system has drifted off target or a special cause has occurred. Otherwise you are tampering.
- Statistical knowledge and data are required to know the difference.

LIST OF SOURCES

Continuing Process Control and Process Capability Improvement, Ford Motor Company, September, 1985.

Coppola, Anthony, Basic Training in TQM Analysis Techniques, Systems Reliability & Engineering Division, Rome Air Development Center, September, 1985.

The Memory Jogger: A Pocket Guide of Tools For Continuous Improvement, Growth Opportunity Alliance of Greater Lawrence (GOAL), 1985.

Robertson, Gordon H., Quality Through Statistical Thinking: Improving Process Control and Capability, American Supplier Institute, 1989.

Structured Problem Solving and the Basic Graphic Methods: Trainer's Manual, Quality and Productivity Group, Naval Research and Development Center, April, 1987.

DEPARTMENT OF DEFENSE

May 30, 1990

PLAN OF INSTRUCTION FOR TOTAL QUALITY MANAGEMENT (TQM)

Quantitative Methods Workshop

Prepared For:
The Office of the
Secretary of Defense

Prepared Through:
The Office of
Personnel Management
Contract Number OPM-87-9038

Prepared By:
Booz • Allen & Hamilton Inc.
Human Resources Management Practice
4330 East West Highway
Bethesda, Maryland 20814

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Preface

The Total Quality Management (TQM) Quantitative Methods Workshop consists of six (6) modules of training. The modules are designed to be delivered in eighteen (18) hours of instruction and encompass three (3) complete training days.

Table of Contents

COURSE DESIGN

Purpose

The purpose of this workshop is to provide participants with analytic skills for TQM problem solving and process improvement. The workshop begins with an introduction to the Plan, Do, Check, Act (PDCA) Cycle, a scientific method used to guide process improvement activities. This problem solving method provides the framework for the remainder of the course, as participants learn how quantitative methods are used to identify problems, identify solutions, and monitor progress throughout the PDCA Cycle.

Participants review elementary statistical theory to ensure a basis of understanding for the quantitative methods described and used later in the course. Concepts covered include categories of data, measures of central tendency, the normal distribution, the use of the standard deviation, and basic sampling techniques. These concepts are discussed in the context of DoD data sets.

Next, participants learn how to use tools often utilized in the Plan and Do phases of the PDCA Cycle. Participants create flow charts and cause and effect diagrams, and apply the techniques to DoD processes.

The next module introduces participants to four tools often used in the Check phase: check sheets, Pareto charts, histograms, and scatter diagrams. For each tool, participants learn what the tool is, why it is used, how to construct the chart/diagram, and how to interpret the data. Participants are given the opportunity to construct and interpret each type of tool using DoD examples.

The final module covers the use of run and control charts in the process control and improvement cycle. Participants learn how to construct run and control charts and interpret run patterns. Next, participants learn how to distinguish between special and common causes of variation, and between process control and capability. These concepts are used in the application of the process control and improvement cycle. Finally, participants learn about managerial action in process control and improvement. The concluding exercise provides a demonstration of the impact of managerial action on process control.

Course Objectives

Upon completion of the course, participants will be able to:

1. Describe the Plan, Do, Check, Act (PDCA) Cycle.
2. List quantitative methods used in each phase of the PDCA Cycle.
3. Compute the mean, mode, median, and standard deviation.
4. Explain how the mean, mode, median, and standard deviation are applied in Total Quality Management.
5. Develop flow charts and caused and effect diagrams.
6. Construct check sheets, Pareto charts, histograms, scatter diagrams, run charts, and control charts.
7. Apply quantitative methods to the study of DoD processes.
8. Describe the process control and improvement cycle.

Module Sub-Objectives

Upon completion of each module, participants will be able to:

Module I

1. Define TQM.
2. Summarize the evolution to TQM.
3. Describe the TQM infrastructure.
4. List the elements of TQM.
5. Describe the focus on process.
6. Explain why quantitative methods are used in TQM.

Module II

1. Describe the scientific methods of inquiry.
2. Compare and contract the Plan, Do, Check, Act (PDCA) cycle with the scientific method.
3. Describe the purpose and focus of the Plan, Do, Check, Act (PDCA) cycle.
4. Describe the steps in the Plan phase.
5. Explain the use of operational definitions in the PDCA cycle.
6. Explain the activities in the Do phase.
7. Describe the method for structuring the data collection process.
8. Identify the purposes of analysis in the Check phase.
9. Describe the activities involved in the Act phase.
10. List the tools for continuous process improvement used in the PDCA cycle.

Module III

1. Explain the distinction between qualitative and quantitative data.
2. Explain and contrast ordinal and nominal qualitative data.
3. Explain and contrast discrete and continuous data.
4. Calculate three measures of central tendency: mean, mode, and median.
5. Analyze DoD data sets and identify the types of data.
6. Describe the normal distribution.
7. Define two measures of variation: range and standard deviation.
8. Calculate the standard deviation of a set of data.
9. Analyze sets of DoD quantitative data and calculate mean, median, mode, range, and

standard deviation.

10. Explain basic sampling techniques.

Module IV

1. Describe the technique of flow charting a process.
2. Apply flow charting to a DoD process.
3. Describe the technique of a cause and effect diagramming.
4. Apply cause and effect diagramming to a DoD process.

Module V

1. Construct and apply check sheet methodology to record and process data.
2. Explain the design concept of a Pareto chart.
3. Display DoD type data in a Pareto chart and interpret the results.
4. Explain the design concept of a histogram.
5. Compare and contrast Pareto charts and histograms.
6. Display DoD type data in a histogram and interpret the results.
7. Describe the design concept of a scatter diagram.
8. Display DoD type data in a scatter diagram and interpret the results.
9. Explain how check sheets, Pareto charts, histograms, and scatter diagrams are used in the Check step of the PDCA cycle.

Module VI

1. Explain the design concept of the run chart.
2. Construct and employ run chart methodology to record and interpret DoD process data.

3. Explain the design concept of the control chart.
4. Compare and contrast run charts and control charts.
5. Calculate and determine control limits on control charts.
6. Distinguish between special and common causes in a DoD process.
7. Identify processes in a state of control versus an uncontrolled state.
8. Explain courses of action for special causes and common causes of DoD process variation.
9. Describe common management actions in response to process variation causes and why they are usually misguided.

Course Schedule

The course schedule is provided in the agenda on pages ii through iv of the student manual.

Course Outline

The course outline is presented as the table of contents on page i of the student manual.

COURSE MANAGEMENT

Instructor Qualifications

Instructors for this course must have attended the TQM Awareness Course and completed the TQM Presenter's Course.

Target Audience

The target audience for the Quantitative Methods Workshop is DoD civilian and military upper- and mid-level managers (SES, GM, Flag Officers, and senior officers -- 06 through 05).

Course Materials

Instructor Materials

- Plan of Instruction
- TQM Quantitative Methods Workshop student manual (SM)
- Vu-graph set
- Answer Key for Selected Exercises (handout)
- Calculators (one for each participant)
- Graph paper and pencils
- Quincunx
- Overhead projector
- Participant evaluation forms
- Participant name tags and table name plates
- Markers and tape

Participant Materials

- TQM Quantitative Methods Workshop student manual (SM)

Course Instructional Methods

The instructional methodology for all six workshop modules will be a combination of lecture, guided group discussion, participant exercises, and case studies.

Participants will be encouraged to take notes in their TQM Quantitative Methods Workshop student manuals. The student manual provides a reduced copy of the vu-graphs used in the Quantitative Methods Workshop and text related to the information in the vu-graphs.

Course References

A list of sources is provided at the end of the student manual.

ANSWER KEY

ANSWERS TO SELECTED EXERCISES

ANSWER KEY

EXERCISE 3-1:

DISTINGUISHING DATA TYPES

Exercise 3-1: Distinguishing Data Types

Scenario 1:

1. Qualitative. None of the data in the table is counteable or measureable; the data are descriptive and categorical.

2. The individuals and the tasks are nominal data because they refer to categories or classes of objects. The priorities are ordinal data; they represent class plus rank.

3. You could average the priorities – that is, you could get a numerical answer – however, the number would be meaningless because there is no way to measure absolute differences between the priorities.

4. No. You could say that Bob needs to completeTask I ahead of Task H because Task I has a higher priority. However, there would be no way to measure an absolute difference between priorities any more than you would be able to establish the distance between two runners in a marathon if the only information you had was that one runner placed first and the other second.

Scenario 2:

1. Quantitative. The data can be counted.

2. Discrete.

3. The data are whole numbers (integers). There cannot be fractions of submarines.

4. Yes, you may average the data, but if the answer is not a whole number, it should be rounded to the nearest whole number because it is not meaningful to talk about a fraction of a sub operating in the Mediterranean.

Scenario 3:

1. Both data sets are quantitative.

2. Both are continuous data. The tire wear example is expressed in whole numbers simply because the measurements are expressed in hundreds of miles, instead of actual tire wear.

ANSWER KEY

EXERCISE 3-2:

CALCULATING THE MEAN, MODE, AND MEDIAN

Exercise 3-2: Calculating the Mean, Mode, and Median

Task 1 Summary:

- The mean is calculated as the sum of all the sample measurements divided by the number of measurements in the sample. The mean for this sample is:

  (5.916 + 4.155 + 5.271 + 5.39 + 4.502 +
  5.182 + 4.489 + 5.995 + 4.208 + 4.219)
  = 49.327/10 = 4.9327.

  Rounding off to three decimal places, we get 4.933.

- The mode is calculated by finding which data element occurs most often. In this data set, there is no data element which occurs more than once. In other words, there is no mode.

- The median is calculated by first ordering the data from high to low.

  4.155, 4.208, 4.219, 4.489, 4.502, 5.182, 5.271, 5.39, 5.916, 5.995

- The rank of the median is (n + 1)/2 or (10+1)/2 = 5.5, which means that the median is located halfway between the fifth and sixth data elements. The fifth data element is 4.502, the sixth is 5.182, and halfway between is (4.502 + 5.182)/2, or 4.842.

- If you add 6.0 hours to the right side of the data set, there is an odd number of data elements, and the median is the number that occupies the calculated rank. The rank of the new data set is (11 + 1)/2 = 6, and the number in the sixth position is 5.182, which is the median of the new data set.

- Which of the three measures of tendency is best? There is no mode so it doesn't need to be considered. The mean and the median are very close together and either would be a good measure of central tendency. As mentioned previously, the best way to represent the data is to use all the measures.

Task 2 Summary:

- You need a good measure of central tendency. In this instance, it is probably best to calculate all three, the mean, the mode, and the median, because it is not obvious which would be the best estimate.

Exercise 3-2: Calculating the Mean, Mode, and Median

- A good way to start is to order the data from lowest to highest in value. You will have to do so to calculate the median anyway, but there are other advantages to ordering the data. First, it makes it much easier to pick out the mode. Second, it is easier to scan the data and get a better idea of its nature and which measure or measures of central tendency to use.

- The ordered data are as follows.

0.32	0.33	0.34	0.38	0.42	0.42
0.43	0.44	0.44	0.45	0.45	0.45
0.45	0.47	0.48	0.49	0.49	0.50
0.50	0.52	0.52	0.52	0.54	0.55

- The mode is the easiest to pick out first. In this case, the mode is 0.45 seconds.

- *The mean is equal to* 10.9 *divided* by 24 which equals 0.4542. It is best to round off to the same number of significant digits as in the sample. So, rounding off to two decimal places, results in a mean of 0.45 seconds.

- Because there is an even number of data points (24), the median is calculated by finding its rank and then determining the point halfway between the two data elements on either side of the rank. The rank of the median is (n + 1)/2 or (24 + 1)/2, which equals 12.5. The twelfth data element is 0.45, as is the thirteenth. Therefore, the median is 0.45, because the average of two equal numbers is equal to the numbers.

- In this scenario, the mean, mode, and median are all equal. You can be fairly confident that the best estimate for the time it takes for the guidance system to lock on a test target is 0.45 seconds. You would probably want to note in your report that all three measures were equal.

- It is interesting to note what happens when the data change. Suppose the last row of the ordered data set were replaced with the following numbers.

0.60 0.60 0.60 0.60 0.60 0.60

Exercise 3-2: Calculating the Mean, Mode, and Median

- The ordered data set would now be:

0.32	0.33	0.34	0.38	0.42	0.42
0.43	0.44	0.44	0.45	0.45	0.45
0.45	0.47	0.48	0.49	0.49	0.50
0.60	0.60	0.60	0.60	0.60	0.60

- The median would stay the same. It would still be 0.45 seconds since the rank or position of the data has not changed. The mode would now be 0.60 seconds, which is a drastic change. The mean would now be 11.35 divided by 24 or 0.47 seconds.

ANSWER KEY

EXERCISE 3-3:

CALCULATING THE STANDARD DEVIATION

Exercise 3-3: Calculating the Standard Deviation

Exercise Summary:

- To calculate the range, simply subtract the lowest value from the highest value. The data are already ordered, so your job is easier. The range for this data set is 46 - 36 = 10.

- The next thing to do is calculate the mean. The mean = $\frac{\Sigma x}{n}$
  = (36 + 36 + 37 + 37 + 41 + 41 + 42 + 43 + 45 + 45 + 46 + 46)/12
  = 495/12 = 41.25 hours.

- The table below illustrates the calculations for the standard deviation of this data set.

x	$(x - \mu)$	$(x-\mu)^2$
36	36 - 41.25 = -5.25	27.56
36	36 - 41.25 = -5.25	27.56
37	37 - 41.25 = -4.25	18.06
37	37 - 41.25 = -4.25	18.06
41	41 - 41.25 = -0.25	0.06
41	41 - 41.25 = -0.25	0.06
42	42 - 41.25 = -0.75	0.56
43	43 - 41.25 = -1.75	3.06
45	45 - 41.25 = -3.75	14.06
45	45 - 41.25 = -3.75	14.06
46	46 - 41.25 = -4.75	22.56
46	46 - 41.25 = -4.75	22.56

		Σ = 168.22

$$s = \sqrt{168.2/11} = 3.97$$

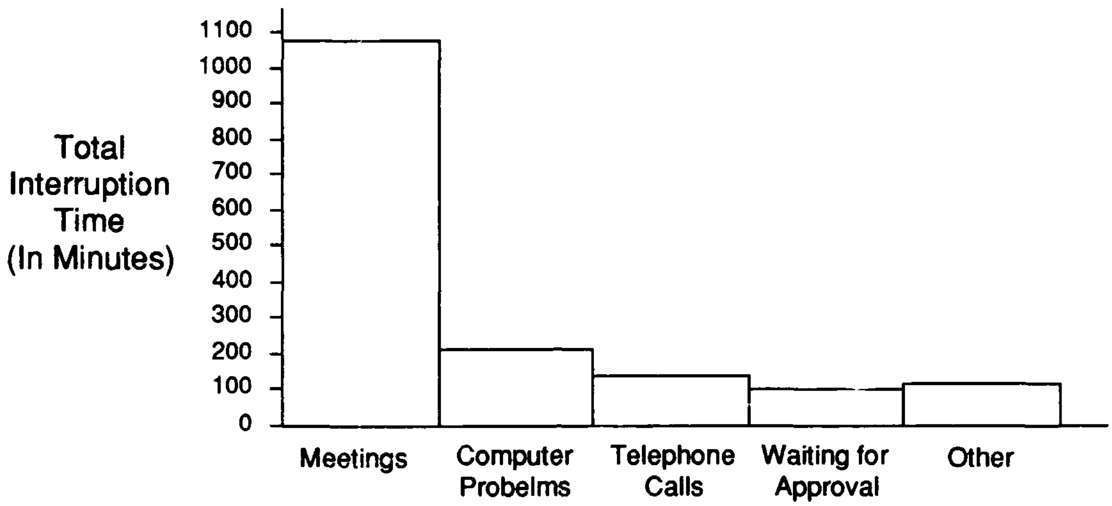
- Remember, for this exercise we are using the standard deviation formula for small samples, so we divide the sum of the squares by n - 1, which is 11.

ANSWER KEY

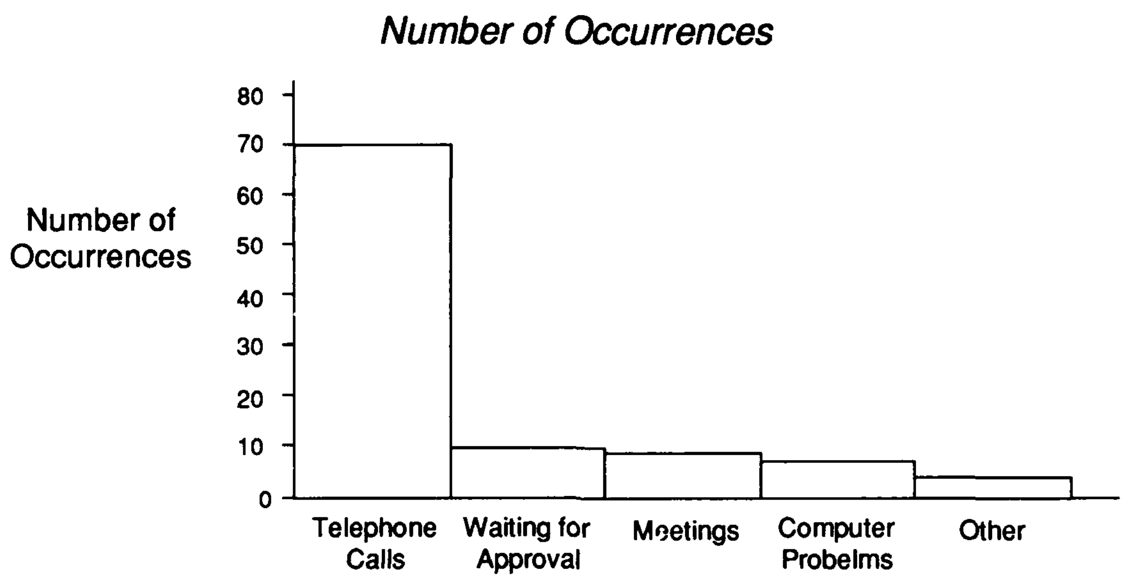
EXERCISE 5-2

CONSTRUCTING A PARETO CHART

Exercise 5-2: Constructing a Pareto Chart



Exercise 5-2: Constructing a Pareto Chart (cont'd)

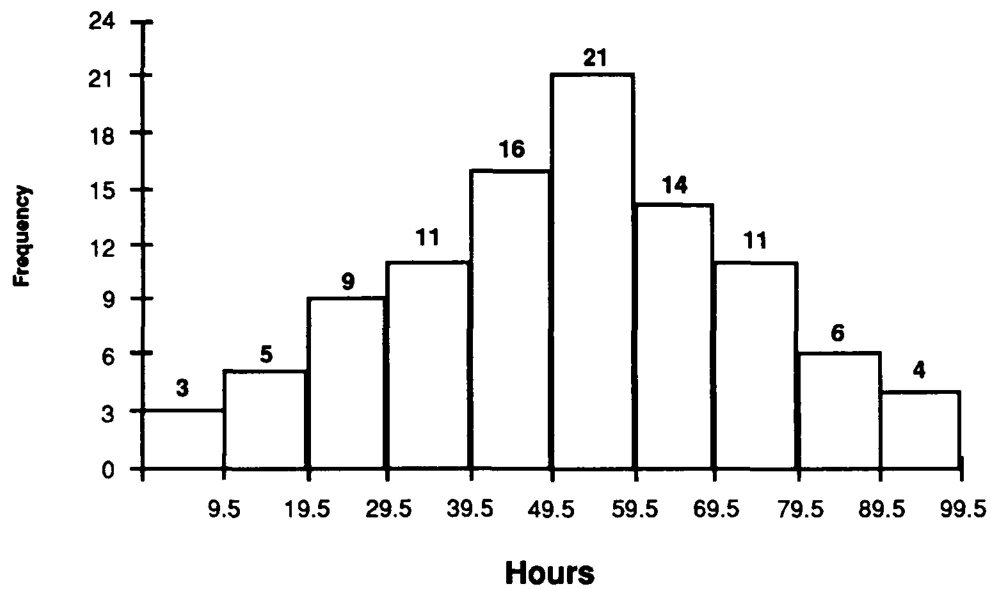


ANSWER KEY

EXERCISE 5-3

CONSTRUCTING A HISTOGRAM

Exercise 5-3: Constructing a Histogram



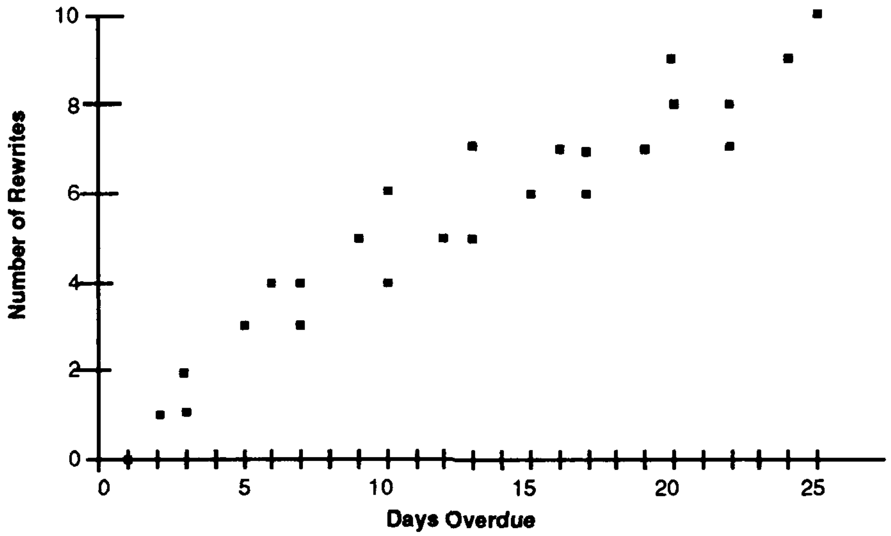
ANSWER KEY

EXERCISE 5-4

CONSTRUCTING A SCATTER DIAGRAM

Exercise 5-4: Constructing a Scatter Diagram

Controlled Correspondence Process: Study of Delays



ANSWER KEY

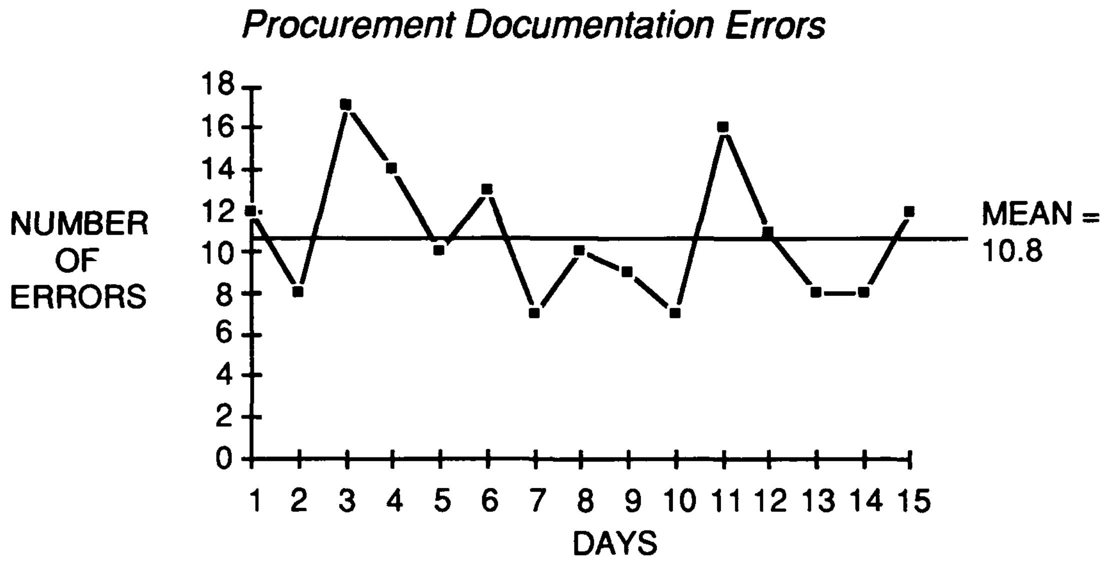
EXERCISE 6-1

BUILDING A RUN CHART

Exercise 6 - 1: Building a Run Chart

Day	Frequency	Relative Frequency
1	12	7.4
2	8	4.94
3	17	10.49
4	14	8.64
5	10	6.17
6	13	8.02
7	7	4.32
8	10	6.17
9	9	5.56
10	7	4.32
11	16	9.88
12	11	6.79
13	8	4.94
14	8	4.94
15	12	7.4
Total	162	100%
Mean	10.8	6.67%

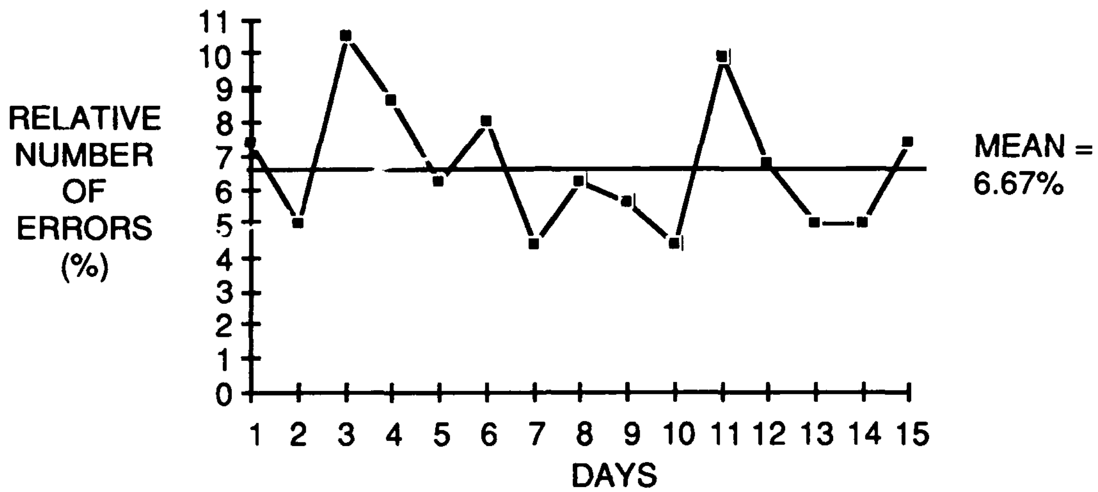
Exercise 6 - 1: Building a Run Chart



- The data you obtained resulted in the above run charts.
- Note that there are no patterns. The points are randomly distributed throughout the 15 day period. There does not appear to be any drifting or cyclical pattern.
- Keep this chart in mind. Our next objective is control charts, and you have already done most of the work to build a control chart in constructing your run chart.

Exercise 6 - 1: Building a Run Chart

Procurement Documentation Errors

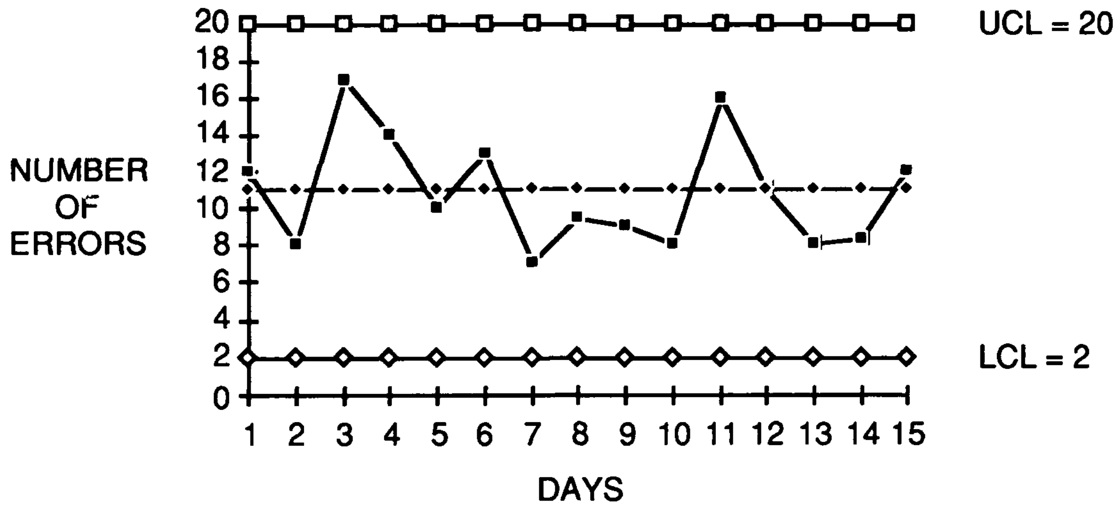


ANSWER KEY

EXERCISE 6-2:

CONSTRUCTING A CONTROL CHART

Exercise 6-2: Constructing a Control Chart



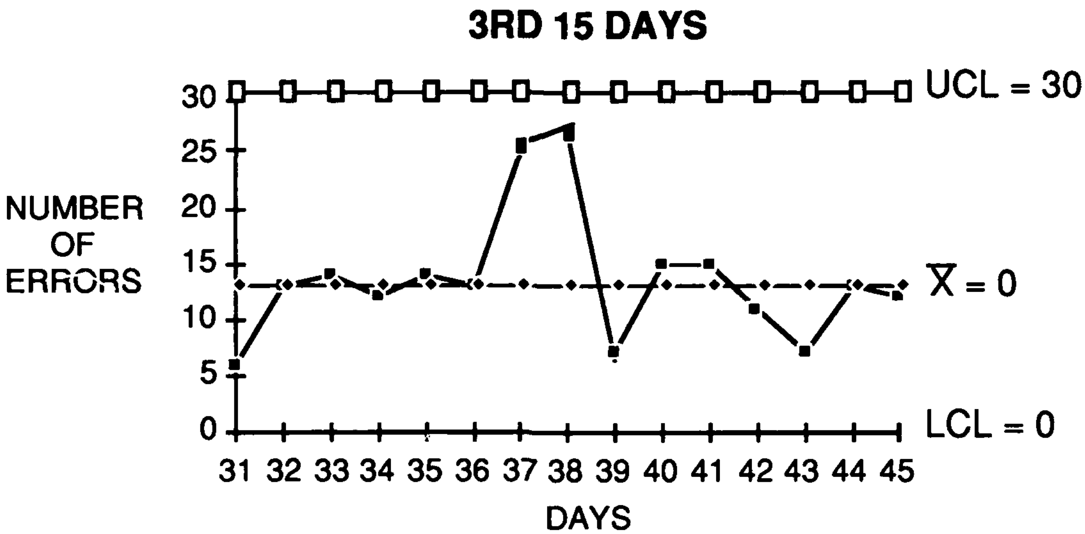
- The data you obtained resulted in the above control chart.
- You can see that it has no pattern associated with it. The points are randomly distributed throughout the 15 day period. That is, there are no patterns evident which indicates that the process your organization follows to complete procurements is stable. There does not appear to be any drifting or cyclical pattern to what is happening.
- Keep this chart in mind. We will use it in other examples and exercises.

ANSWER KEY

EXERCISE 6-3

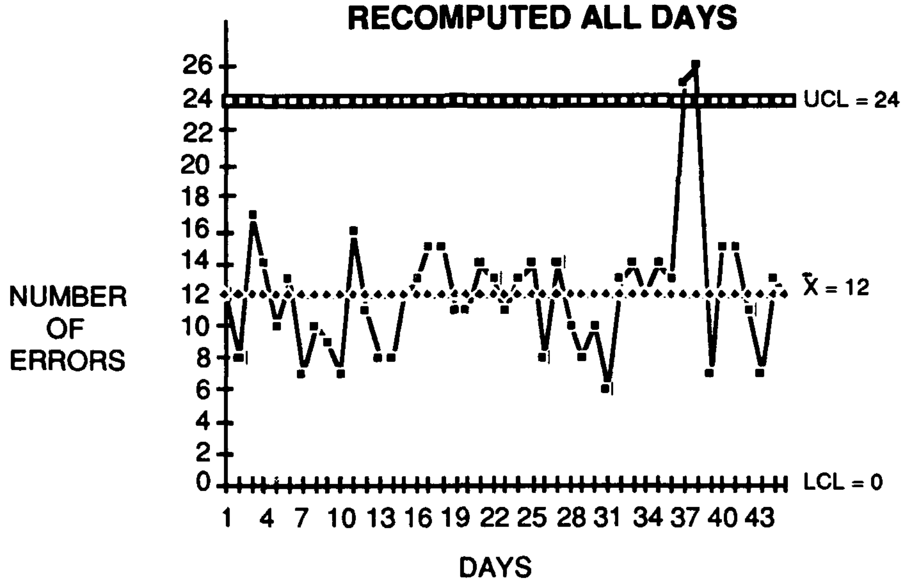
CONSTRUCTING A CONTROL CHART TO DETERMINE PROCESS CONTROL

Exercise 6-3: Constructing a Control Chart to Determine Process Control



- The chart above represents your third 15 day period. You've calculated the mean and the control limits, and plotted your data. The mean is13.53, and the standard deviation is 5.64. Thus, the UCL = 30.45 and the LCL = 0.

Exercise 6-3: Constructing a Control Chart to Determine Process Control



- The re-calculated chart for the entire 45 days is shown above. The mean is 12.1 and the standard deviation is 4.04. Thus, the UCL = 24.2 and the LCL = 0.

MODULE ONE

TQM REVIEW

Module One Objectives

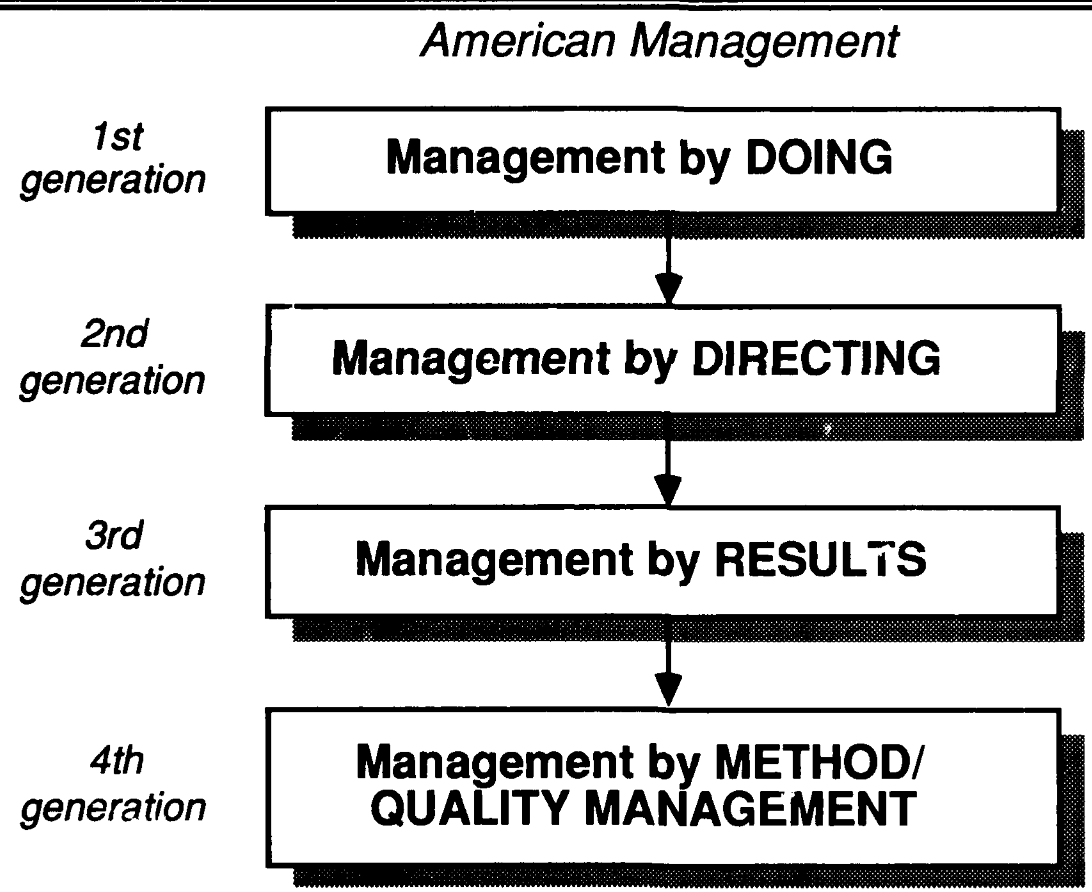
Upon completion of this module, the participant will be able to:

- Define TQM.
- Summarize the evolution to TQM.
- Describe the TQM infrastructure.
- List the elements of TQM.
- Describe the focus on process.
- Explain why quantitative methods are used in TQM.

DoD TQM Definition

Total Quality Management (TQM) is both a **philosophy** and a set of **guiding principles** that represent the foundation of a **continuously improving** organization. TQM is the application of **quantitative methods** and **human resources** to improve the material and services supplied to an organization, and the degree to which the **needs of the customer** are met, now and in the future. TQM integrates fundamental management techniques, existing improvement efforts, and technical tools under a **disciplined approach** focused on continuous improvement.

Evolution to Total Quality Management



Total Quality Management Infrastructure

Executive Steering Committee

- The *Executive Steering Group* and *senior management* are responsible for providing leadership.
- Creating a quality culture is a result of a long-term commitment.
- Leaders must drive out fear.
- Top-level leaders must accept the challenge.

Total Quality Management Infrastructure

Quality Management Boards (QMBs)

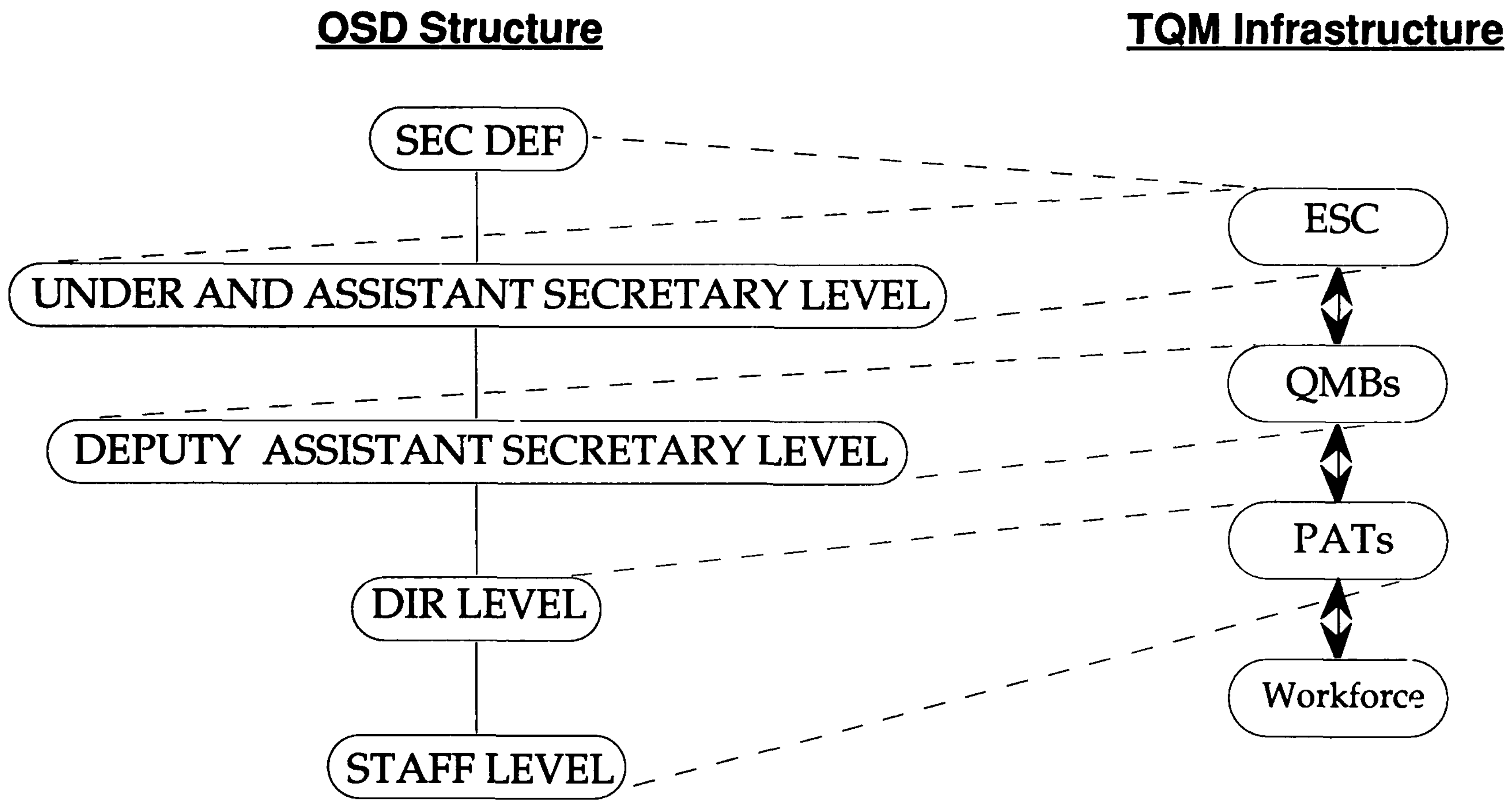
- Include a senior member.
- Identify improvement opportunities within issue areas.
- Are responsible for changing processes when change is needed.
- Remove barriers.
- Establish Process Action Team (PATs) and facilitate progress.
- Provide TQM leadership.

Total Quality Managment Infrastructure

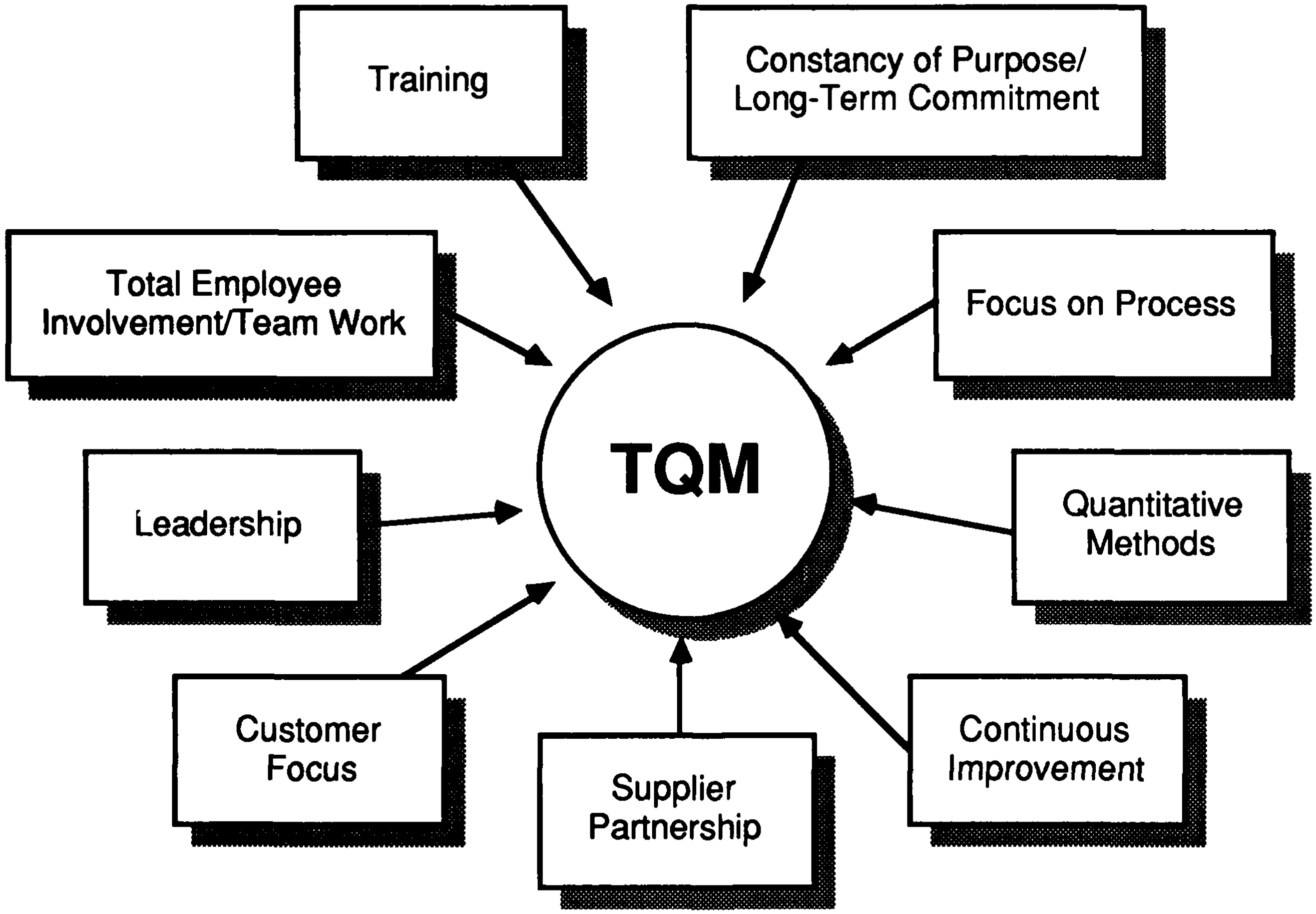
Process Action Teams (PATs)

- PATs are formed to deal with specific process problems and to resolve issues.
- Roles of QMBs and PATs are complementary.
- QMBs focus on more permanent and larger issues than those addressed by PATs.
- Involving many people in the improvement process is critical to making the QMB/PAT structure work.

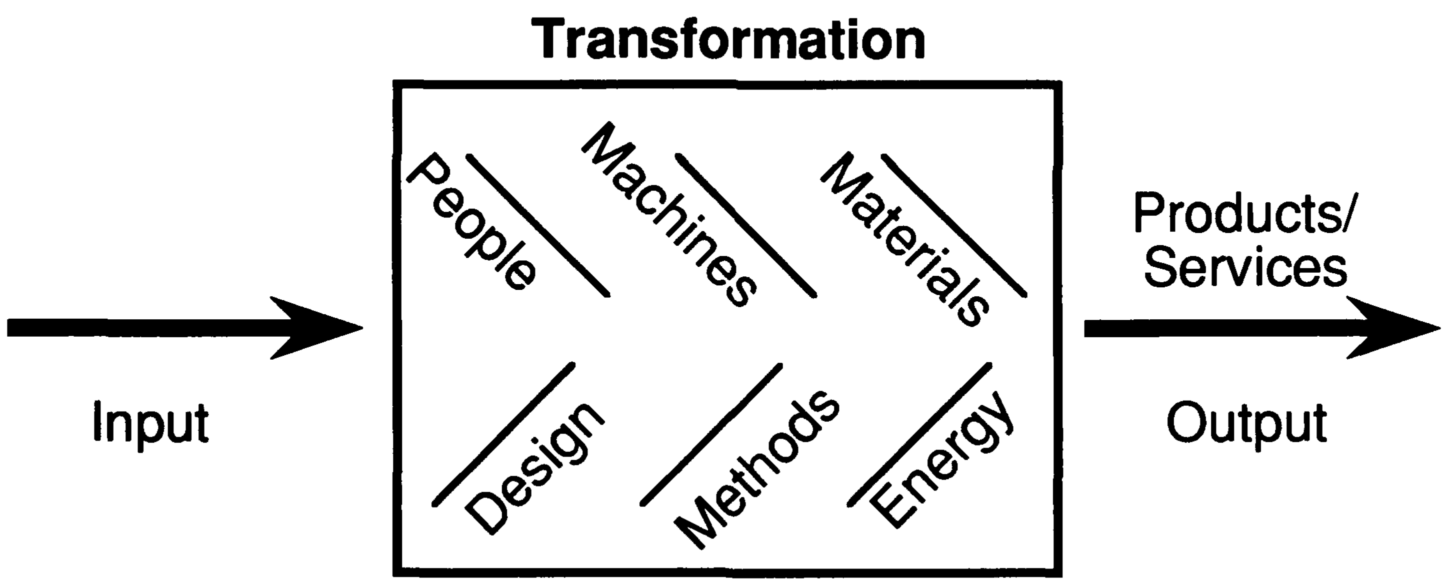
TQM and the OSD Structure



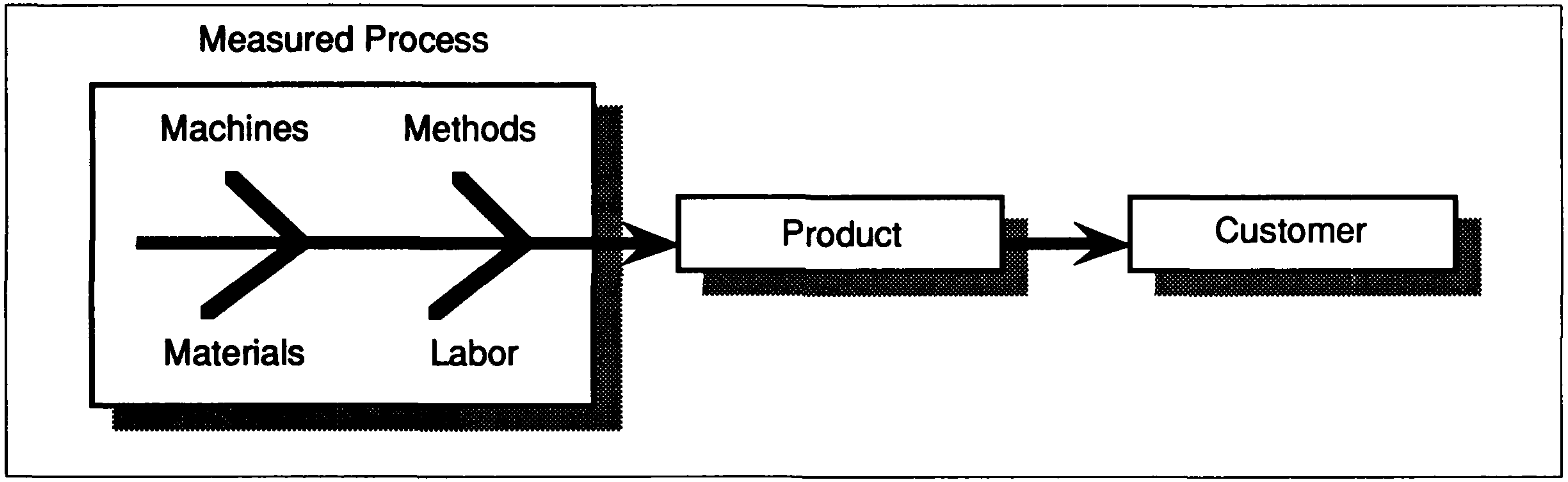
TQM Elements



Focus on Process



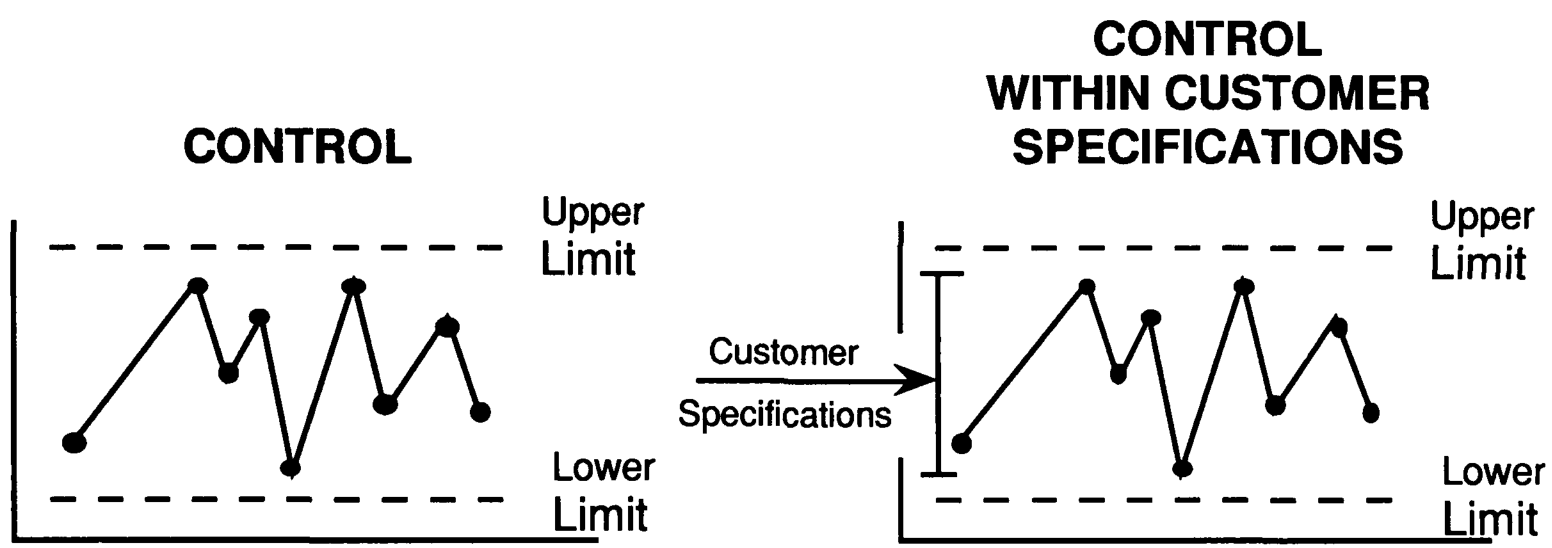
Focus on Process



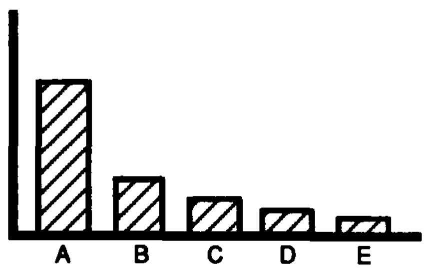
- Focuses on the processes by which work gets done, rather than on a hierarchy of individual accountability.
- Provides the methods to study and improve processes for better results.

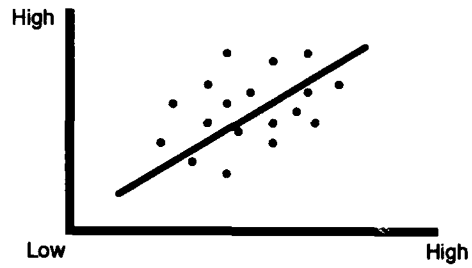
Focus on Process

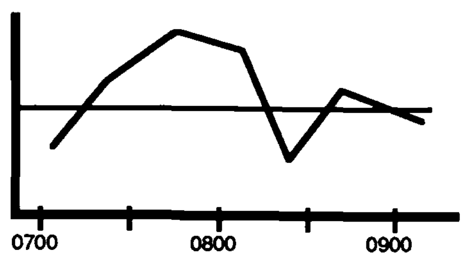
Process Control



Quantitative Methods







- Identify problems
- Identify solutions
- Monitor progress

Data-based decision making

Group Discussion

THAT WAS THEN...

...THIS IS NOW

- What have you done to improve quality since awareness training?
- Have you seen TQM activity in your work place?

MODULE TWO

SCIENTIFIC METHOD AND THE PLAN, DO, CHECK, ACT CYCLE

Module Two Objectives

Upon completion of this module, the participant will be able to:

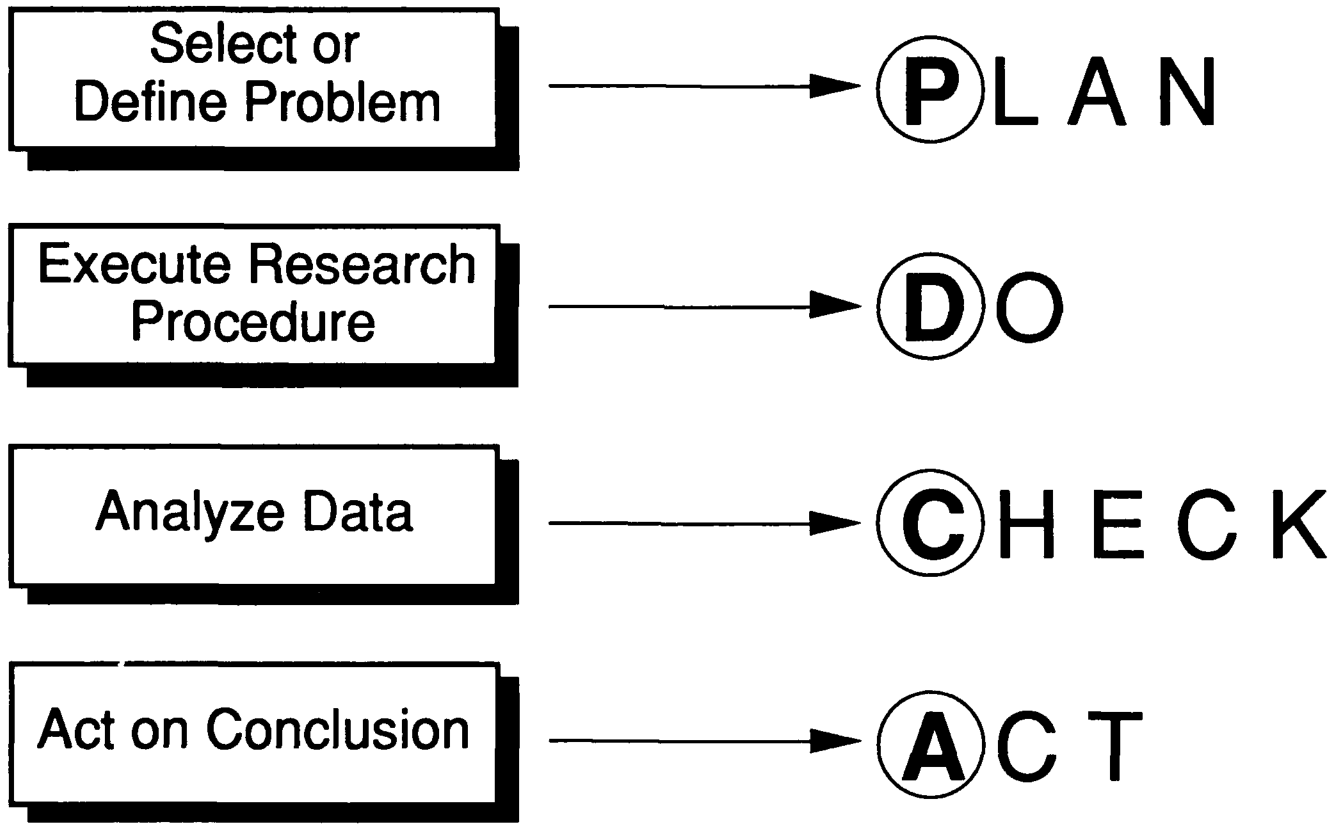
- Describe the scientific method of inquiry.
- Compare and contrast the Plan, Do, Check, Act (PDCA) cycle with the scientific method.
- Describe the purpose and focus of the Plan, Do, Check, Act (PDCA) cycle.
- Describe the steps in the Plan phase.
- Explain the use of operational definitions in the PDCA cycle.
- Explain the activities in the Do phase.
- Describe the method for structuring the data collection process.
- Identify the purposes of analysis in the Check phase.
- Describe the activities involved in the Act phase.
- List the tools for continuous process improvement used in the PDCA cycle.

Scientific Method

- Explain
- Predict
- Control

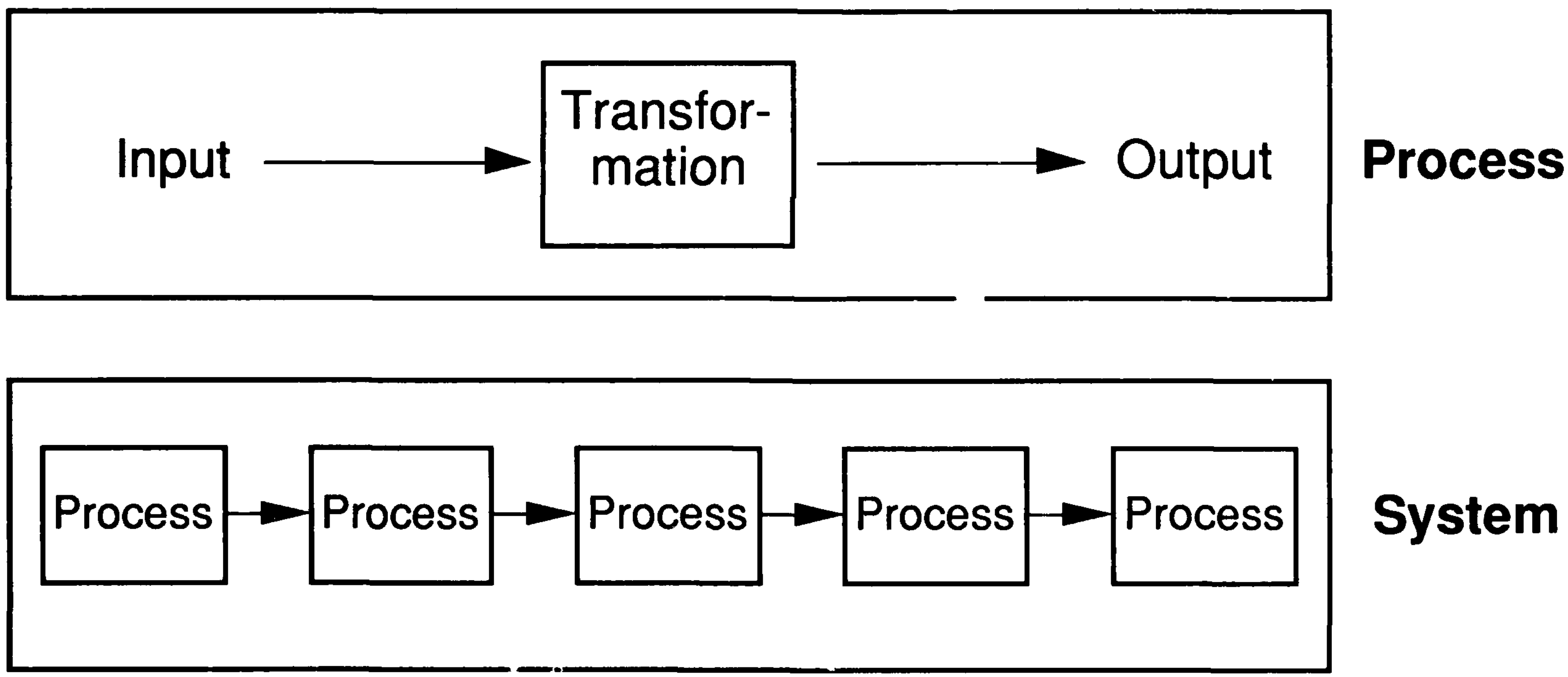
Objectively

Scientific Method and PDCA Cycle



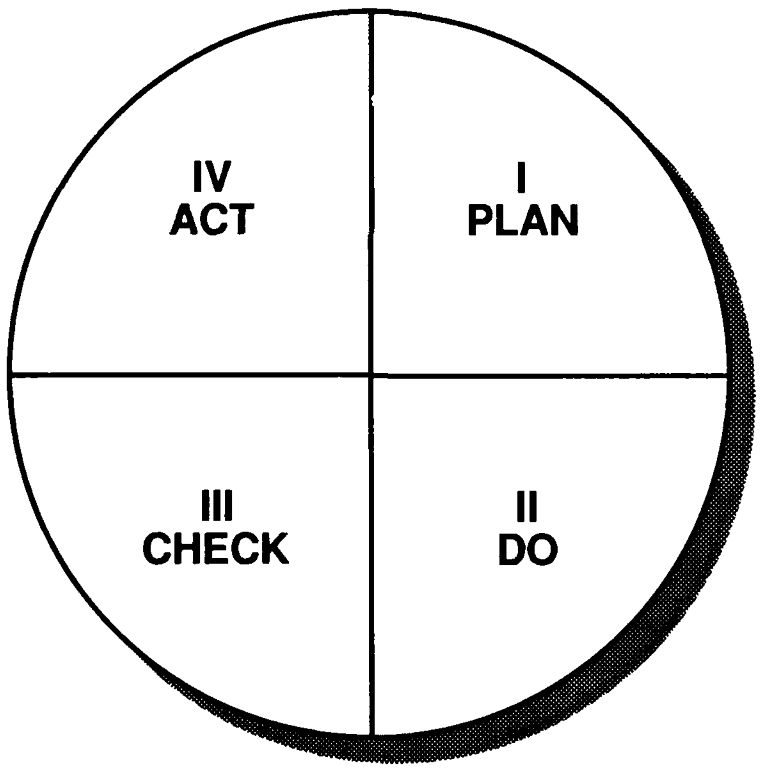
PDCA Cycle

Focus on Process Improvement

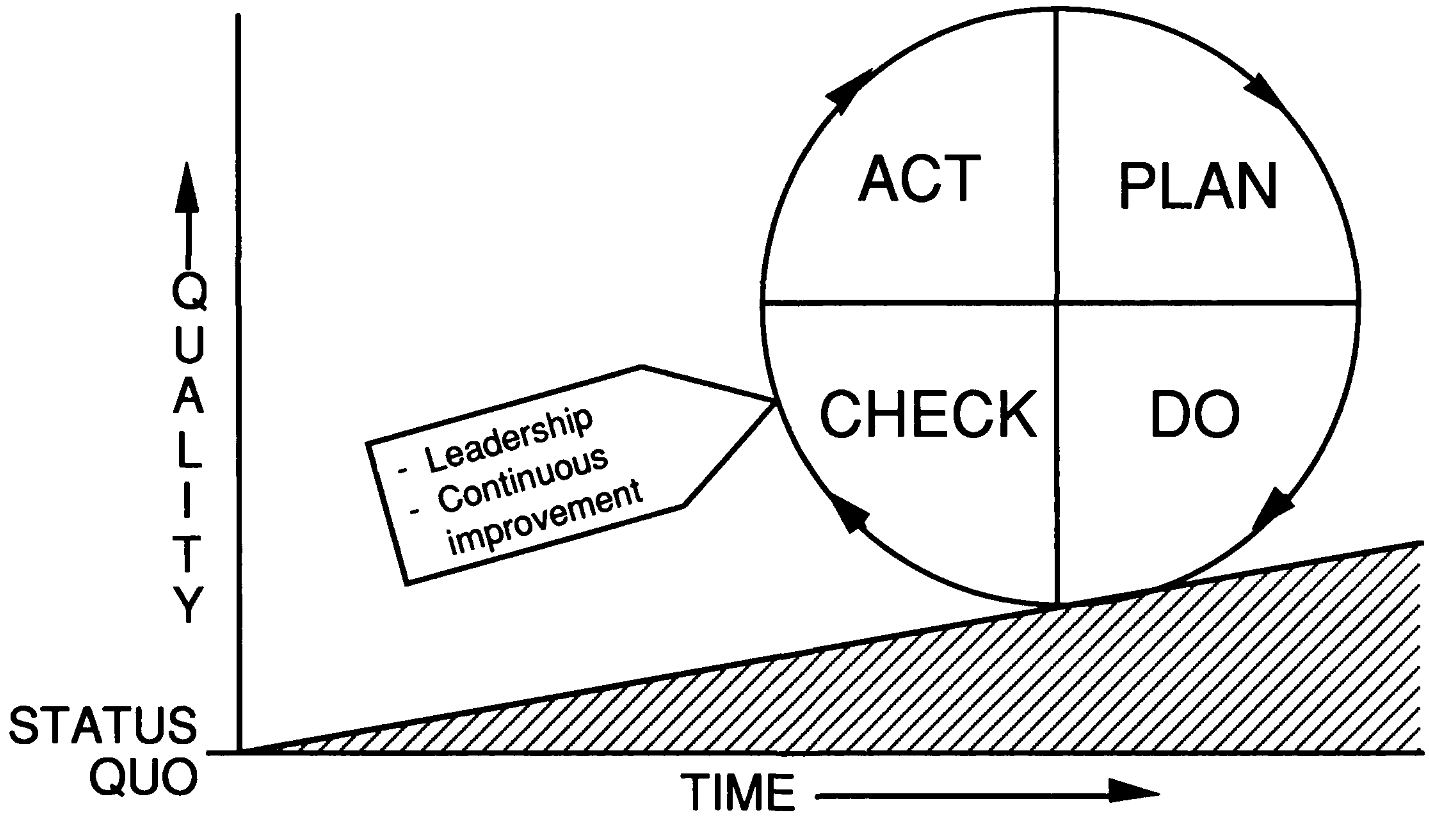


PDCA Cycle

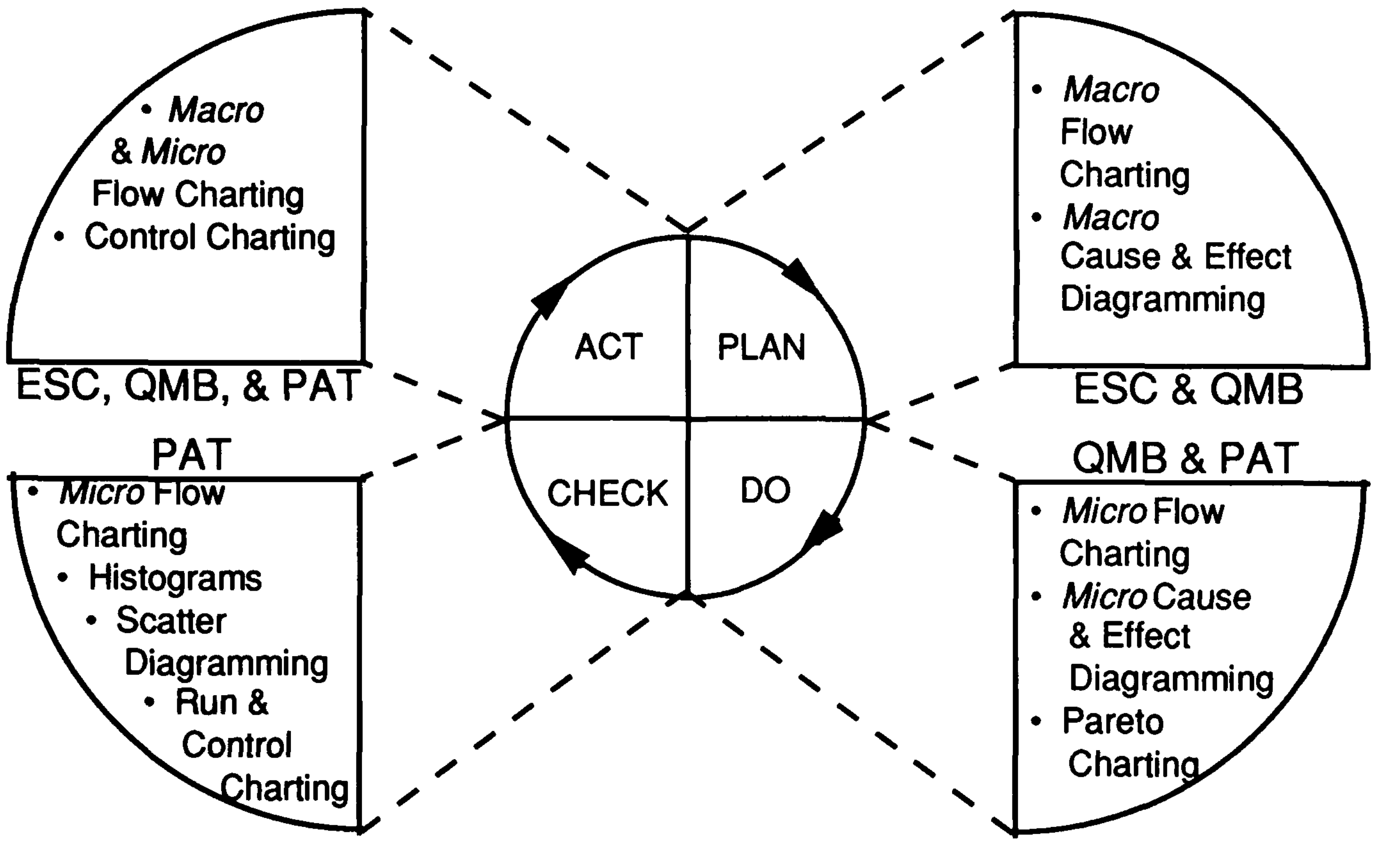
Managing Process Improvement



PDCA Cycle

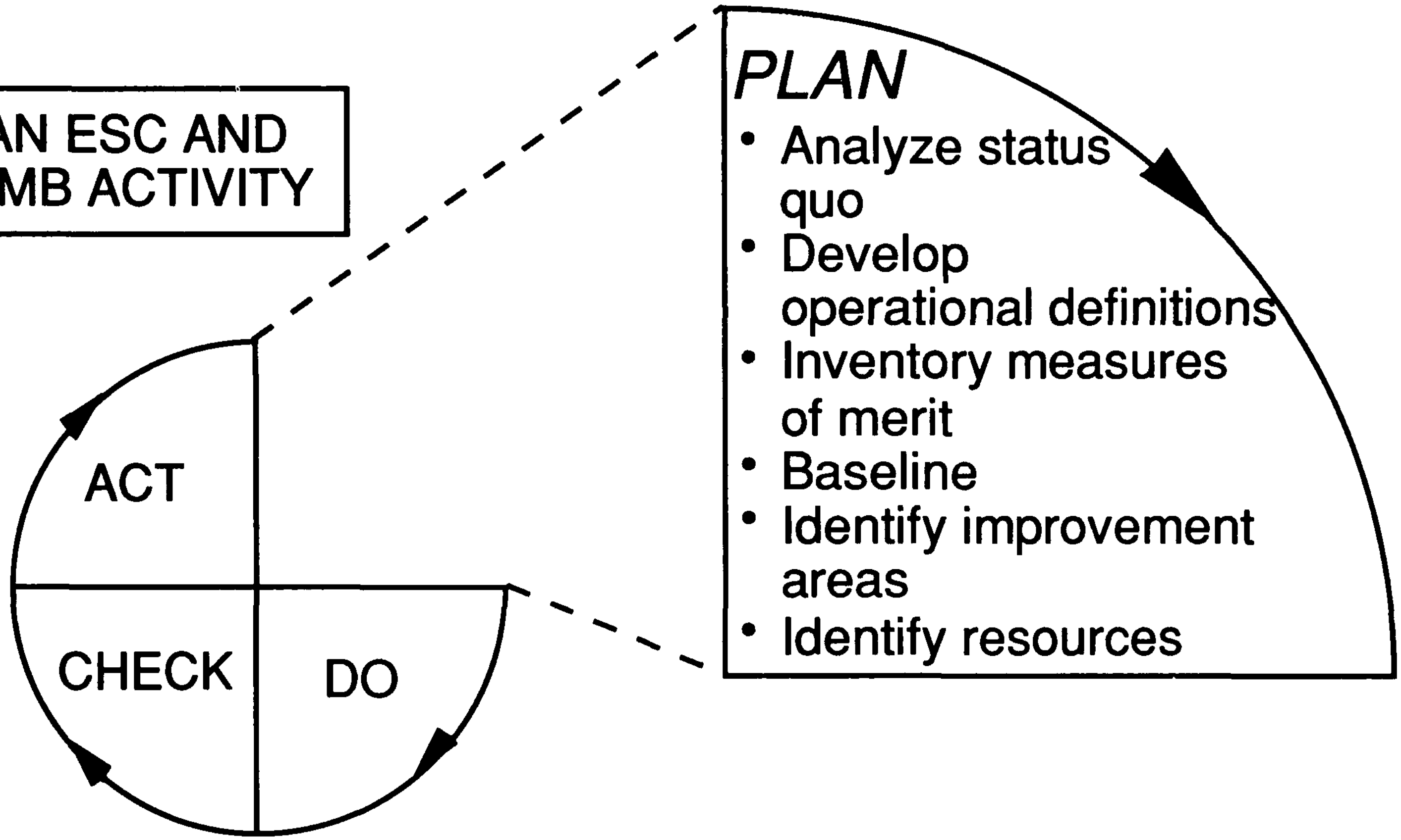

ACT
PLAN
CHECK
DO
- Leadership
- Continuous improvement
QUALITY
STATUS QUO
TIME

PDCA Cycle


• *Macro*
& Micro
Flow Charting
• Control Charting
ESC, QMB, & PAT
PAT
• *Micro* Flow
Charting
• Histograms
• Scatter
Diagramming
• Run &
Control
Charting
ACT
PLAN
CHECK
DO
• *Macro*
Flow
Charting
• *Macro*
Cause & Effect
Diagramming
ESC & QMB
QMB & PAT
• *Micro* Flow
Charting
• *Micro* Cause
& Effect
Diagramming
• Pareto
Charting

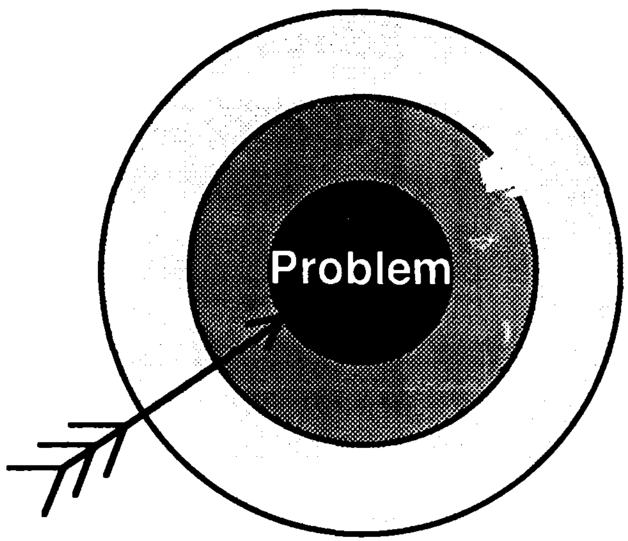
Planning in the PDCA Cycle

AN ESC AND QMB ACTIVITY



Planning in the PDCA Cycle

Identify and Define Problem



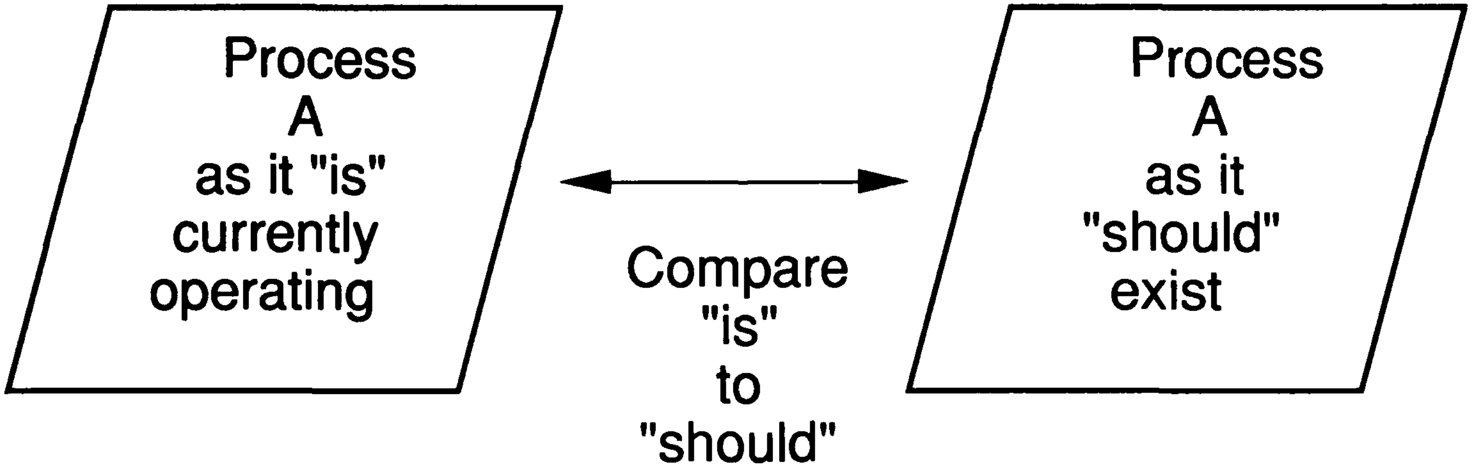
Target Problem

Tools:

- Flow Chart
- Cause and Effect Diagram

Planning in the PDCA Cycle

Baseline Activity



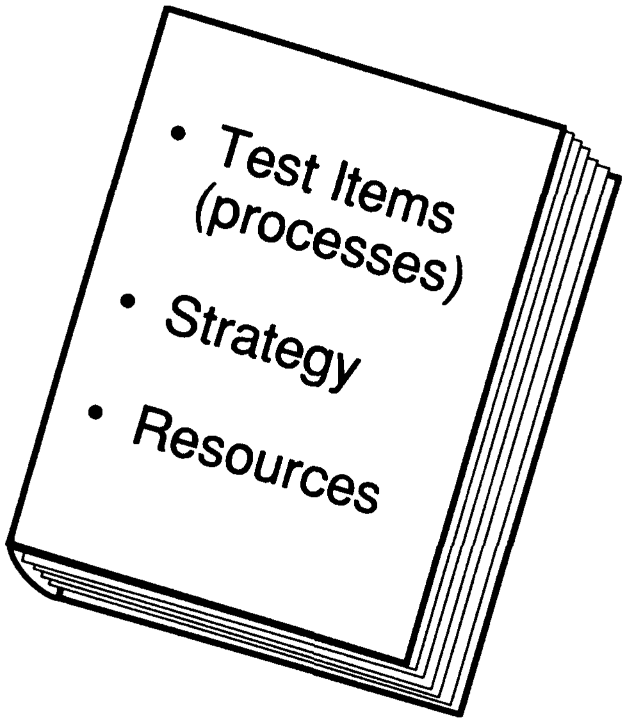
Planning in the PDCA Cycle

State Improvement Objectives and Measures of Performance

- Identify customer/supplier relations
- Determine customer needs (operational definitions)
- Identify measures of merit
- Develop improvement objectives

Planning in the PDCA Cycle

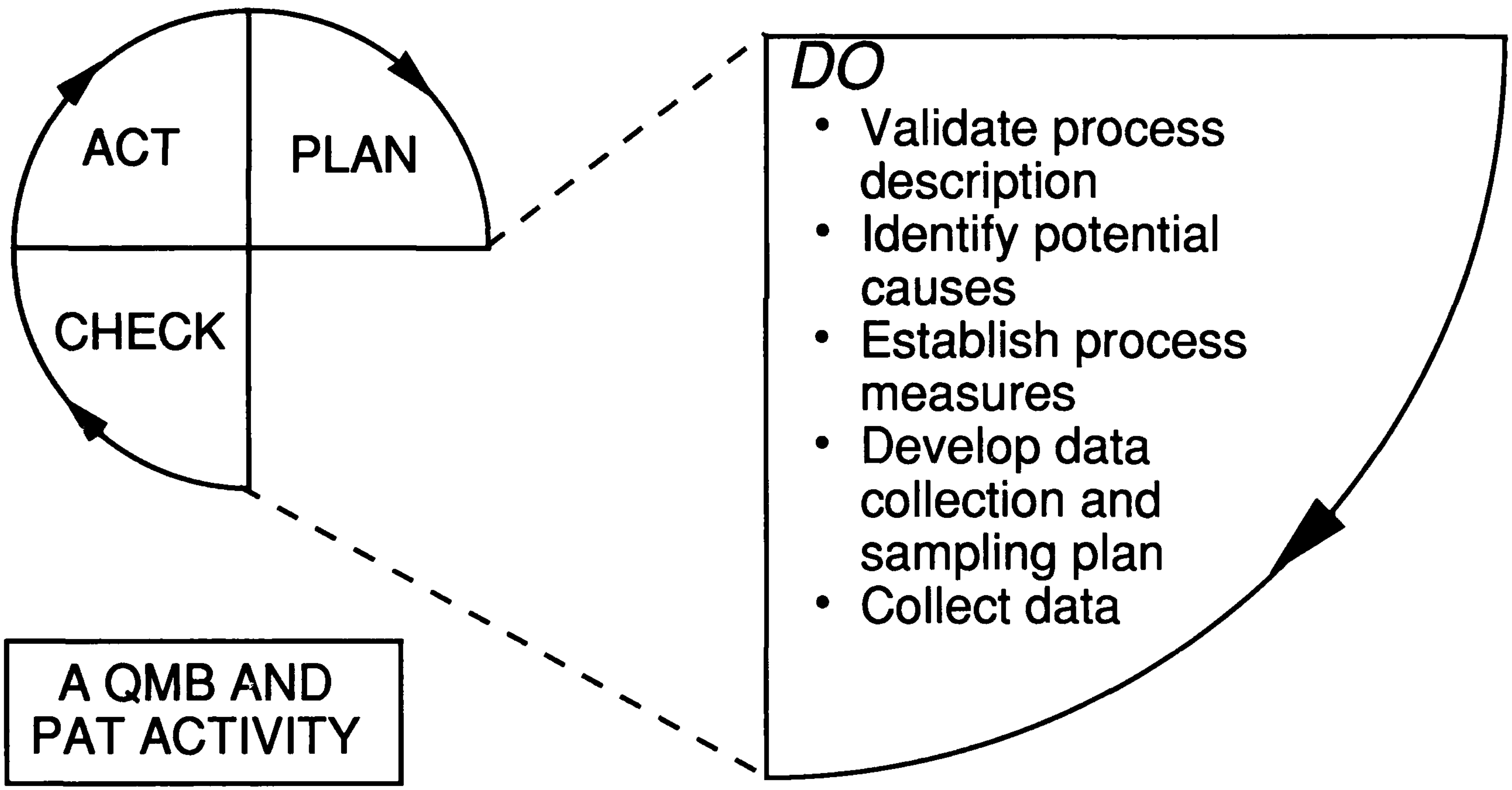
Design Research Plan



Group Discussion

PLANNING IN THE PDCA CYCLE

Doing in the PDCA Cycle



A QMB AND PAT ACTIVITY

Scientific Method and PDCA

Operational Definitions

- Global
- Specific

Doing in the PDCA Cycle

Specific Operational Definitions

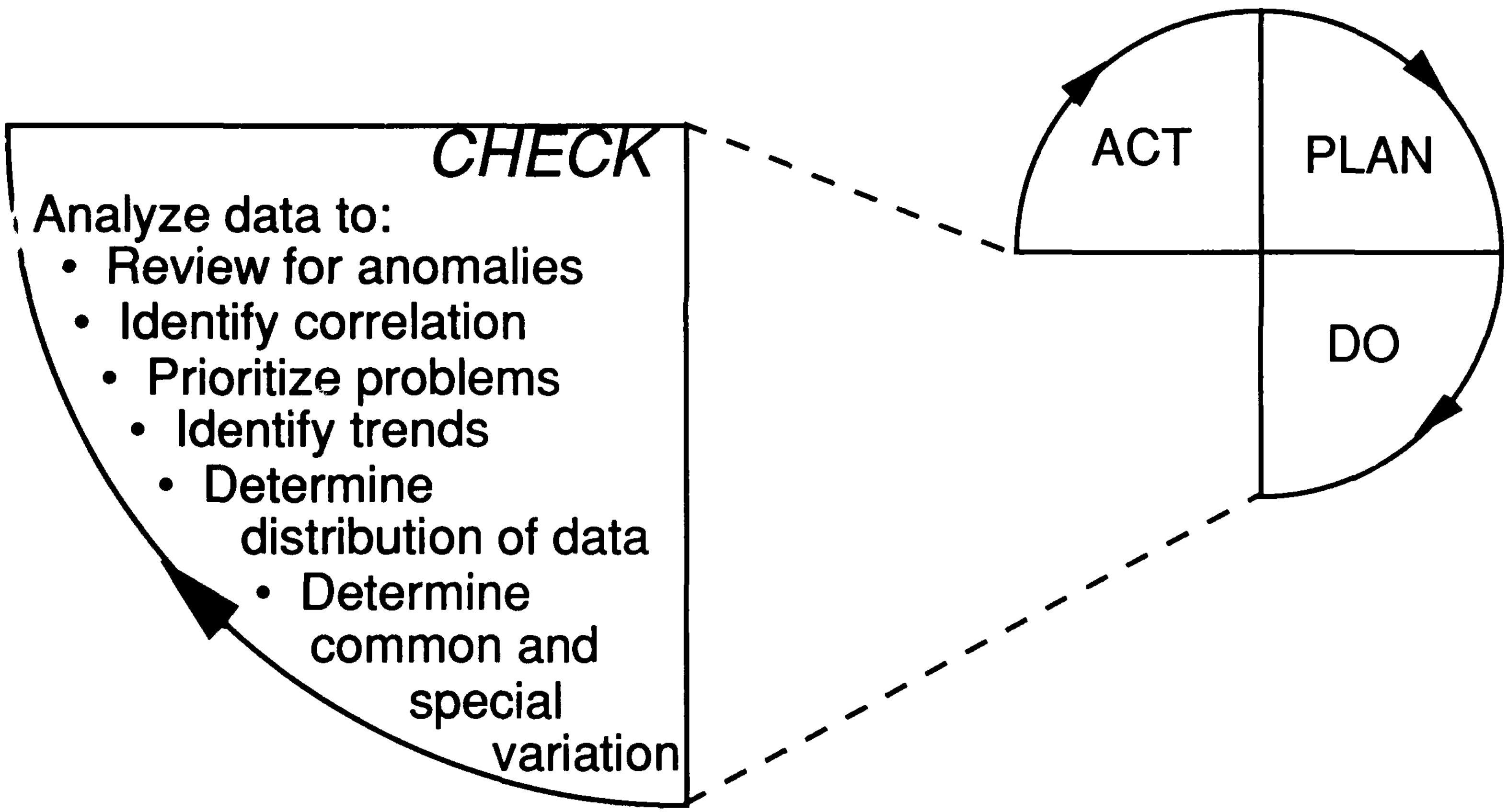
- Specific operational definitions express ideas and processes in terms of observable and measurable parameters.
- Without operational definitions, accurate data collection is impossible.
- Everyone must have a <u>common understanding</u> of an operational definition; everyone does not necessarily have to agree with the definition.
- Operational definitions are best developed through repeated small pilot testing.

Doing in the PDCA Cycle

Data Collection and Sampling Plan

- What kind of data to collect
- Where and how to collect (sampling plan)
- When to collect
- How to protect and archive

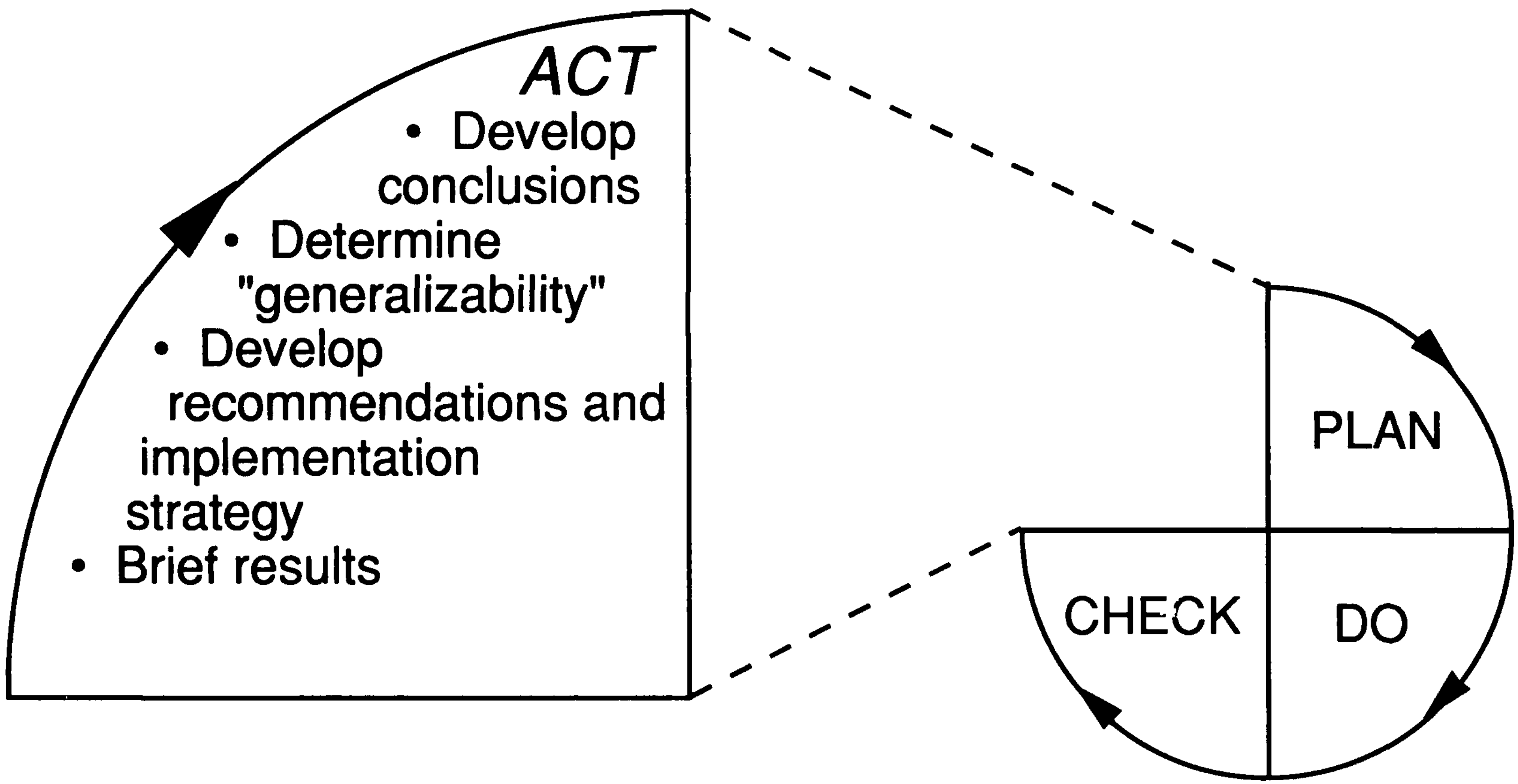
Checking in the PDCA Cycle



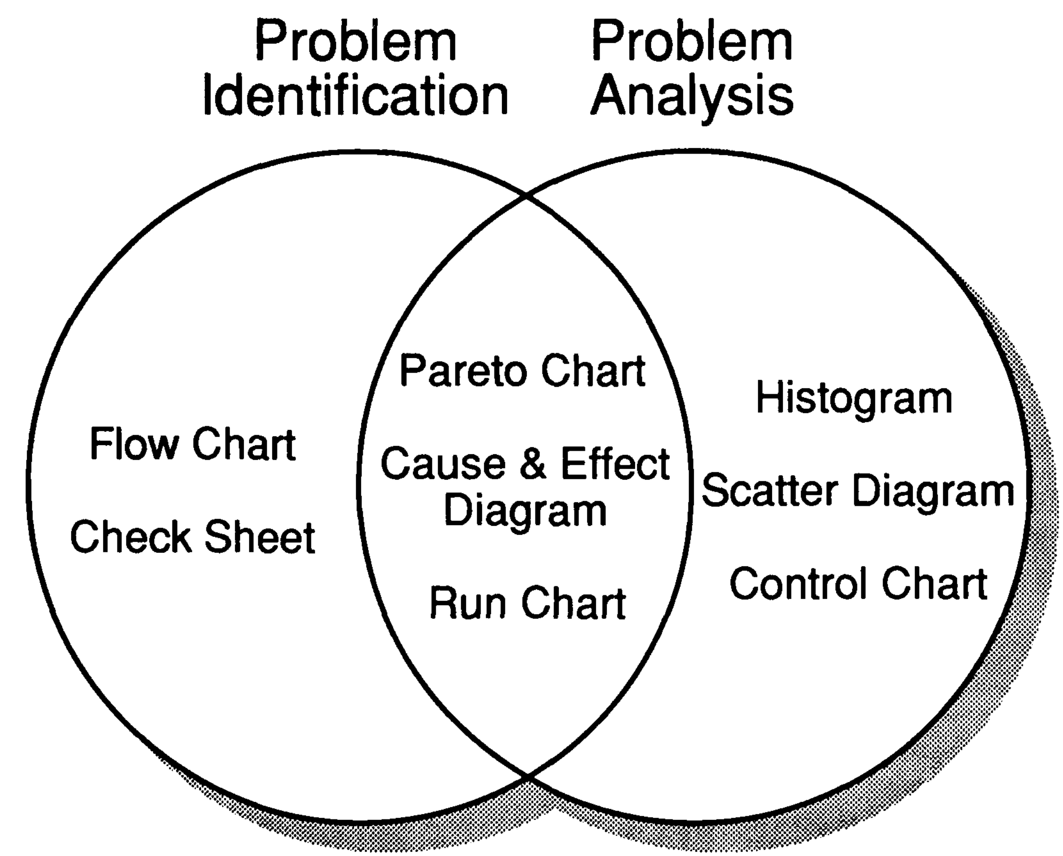
Checking in the PDCA Cycle

PURPOSE	*TOOL*
• Prioritize Problems	Pareto Chart
• Determine Distribution of Data	Histogram
• Identify Correlations	Scatter Diagram
• Identify Trends	Run Chart
• Determine Common and Special Causes of Variation	Control Chart

Acting in the PDCA Cycle



Tools for Continuous Improvement in the PDCA Cycle



MODULE THREE

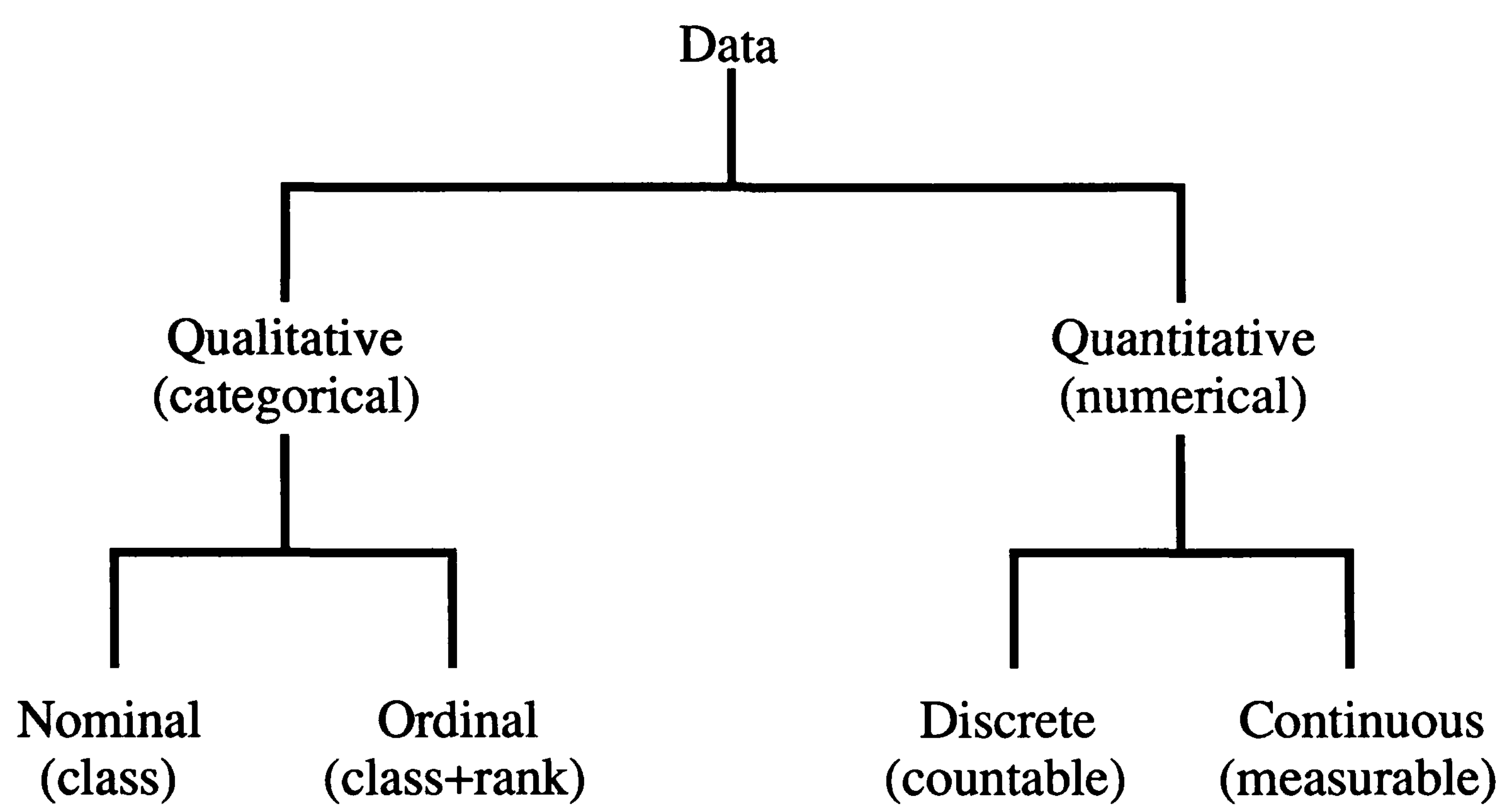
STATISTICAL THEORY AND TOOLS

Module Three Objectives

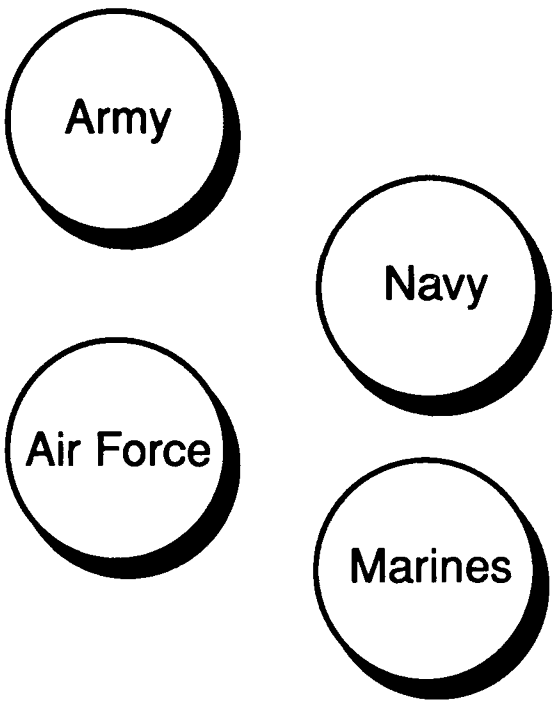
Upon completion of this module, participants will be able to:

- Explain the distinction between qualitative and quantitative data.
- Explain and contrast ordinal and nominal qualitative data.
- Explain and contrast discrete and continuous quantitative data.
- Calculate three measures of central tendency: mean, mode, and median.
- Analyze DoD data sets and identify the types of data.
- Describe the normal distribution.
- Define two measures of variation: range and standard deviation.
- Calculate the standard deviation of a set of data.
- Analyze sets of DoD quantitative data and calculate mean, median, mode, range, and standard deviation.
- Explain basic sampling techniques.

Categories of Data



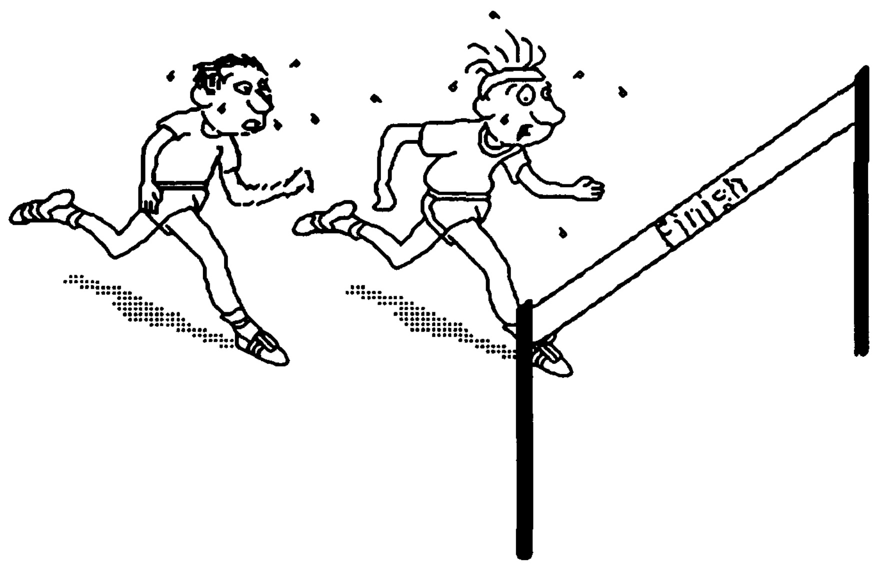
Qualitative Data



NOMINAL DATA

- Classes or categories of objects
- Cannot be ranked
- Used only for descriptive purposes

Qualitative Data

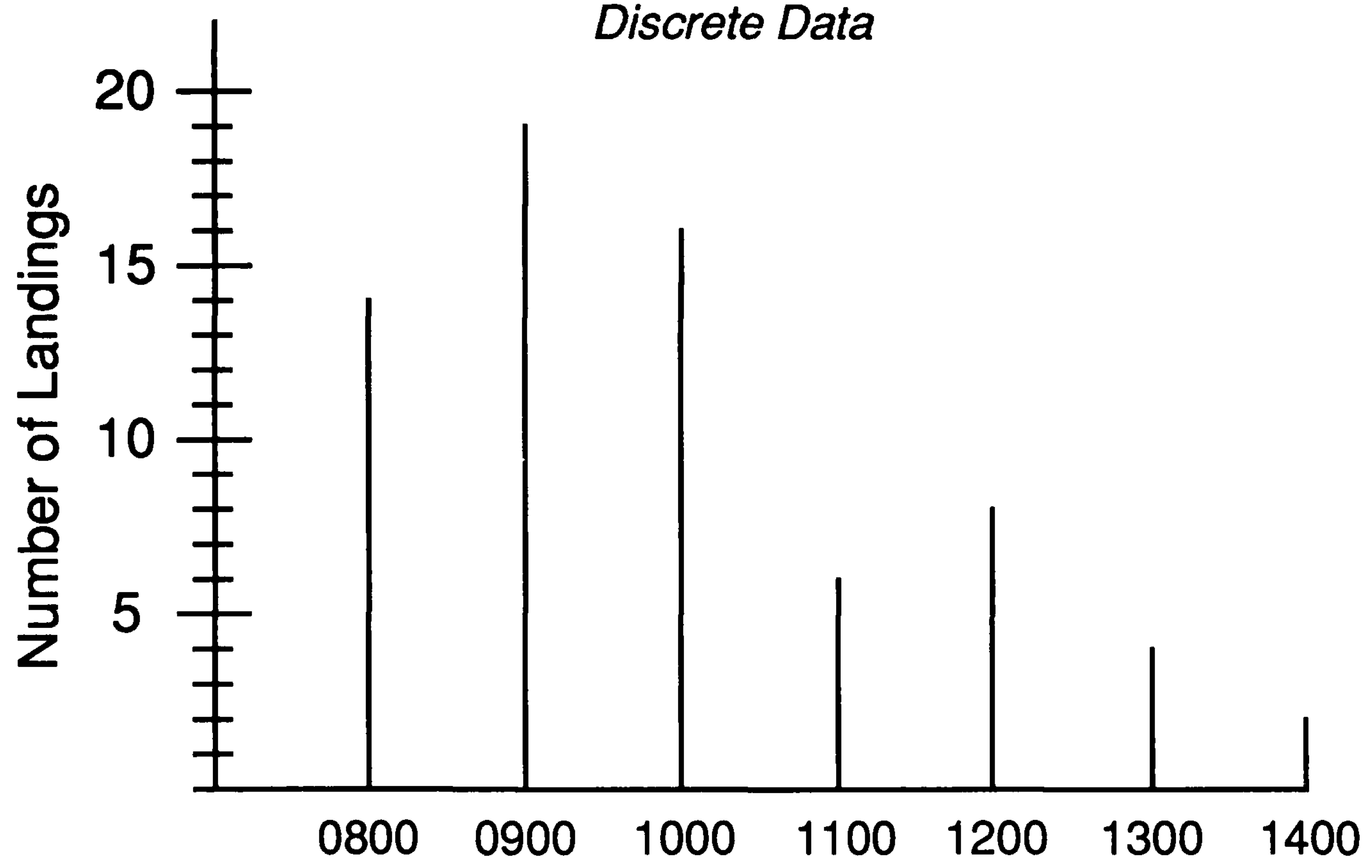


ORDINAL DATA

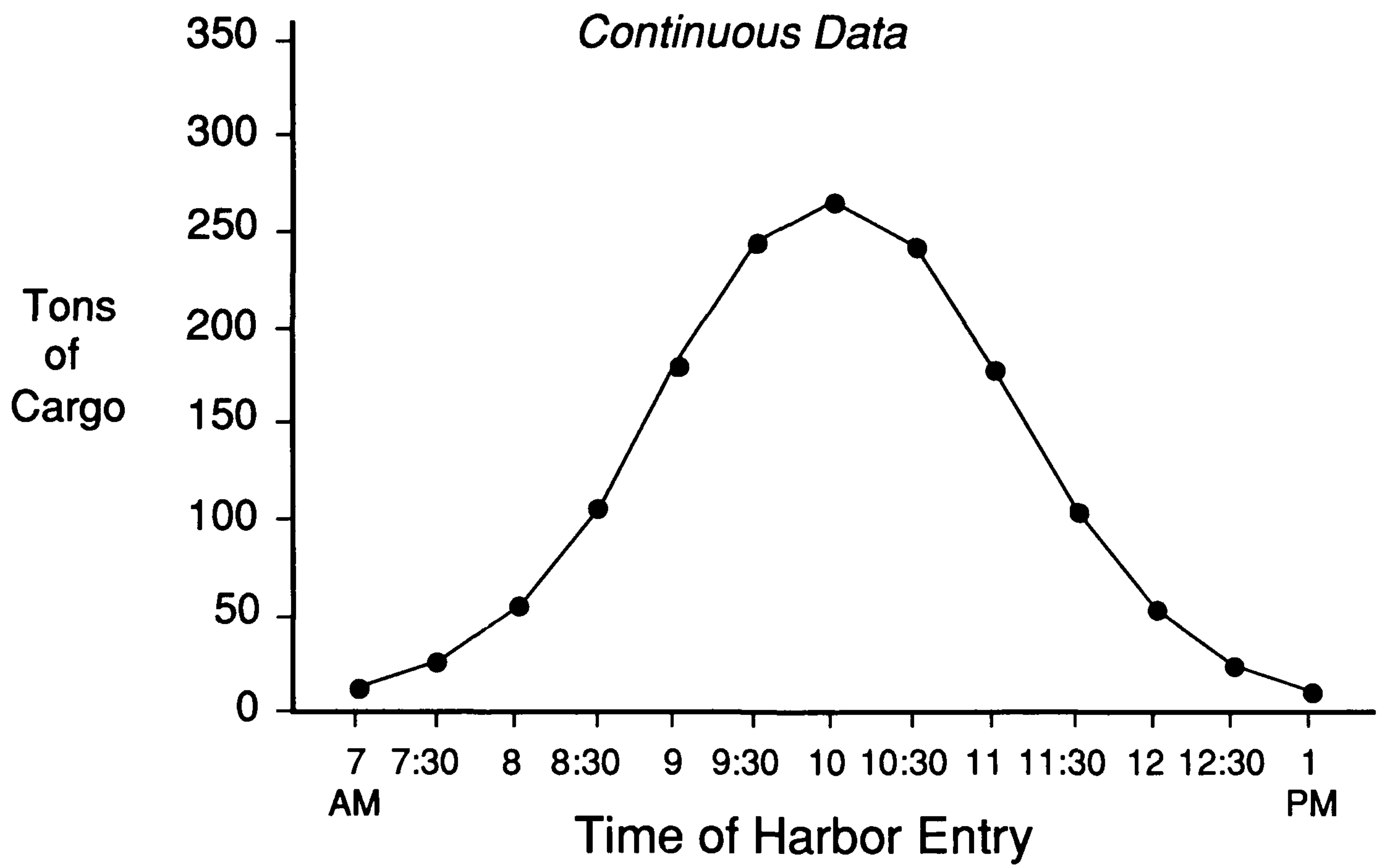
- Classes or categories of objects that can be ranked
- No way to distinguish magnitude between data points
- Used only for descriptive purposes

Quantitative Data

Discrete Data



Quantitative Data



Quantitative Data

Level of Significance

- Measure only to level you need.
- Avoid
  "Measuring with a micrometer,
  Marking with a paint brush,
  Cutting with an axe."

Exercise 3-1

DISTINGUISHING DATA TYPES

Measures of Central Tendency

Tools to summarize or describe the distribution in a data set:

- **Mean**
- **Mode**
- **Median.**

Measures of Central Tendency

The Mean

$$\mu = \frac{\sum x}{n} = \frac{\text{Sum of all the data points}}{\text{Number of data points}}$$

Measures of Central Tendency

Mean of Means

$$20 + 20 + 20 + 20 + 20 = 100 \qquad \text{Mean} = 20$$
$$10 + 10 + 10 + 10 + 10 = \underline{\ 50\ } \qquad \text{Mean} = \underline{10}$$
$$150/10 \qquad\qquad 30/2$$

Mean of Data = 15 = Mean of Means = 15

It is acceptable to average means if the data sets are approximately equal in number.

Measures of Central Tendency

Mean of Means

$$
\begin{array}{lrl}
20 + 20 + 20 + 20 + 20 & = 100 & \quad \text{Mean} = 20 \\
10 + 10 + 10 & = \underline{\ \ 30} & \quad \text{Mean} = \underline{10} \\
& 130/8 & \quad 30/2
\end{array}
$$

Mean of Data = 16.25 $\neq$ Mean of Means = 15

It is <u>not</u> acceptable to average means if the data sets are not approximately equal in number. If data sets are unequal in number, use a *weighted mean*.

Measures of Central Tendency

The Mode

Definition:

Data point that occurs most frequently in the data set.

Example:

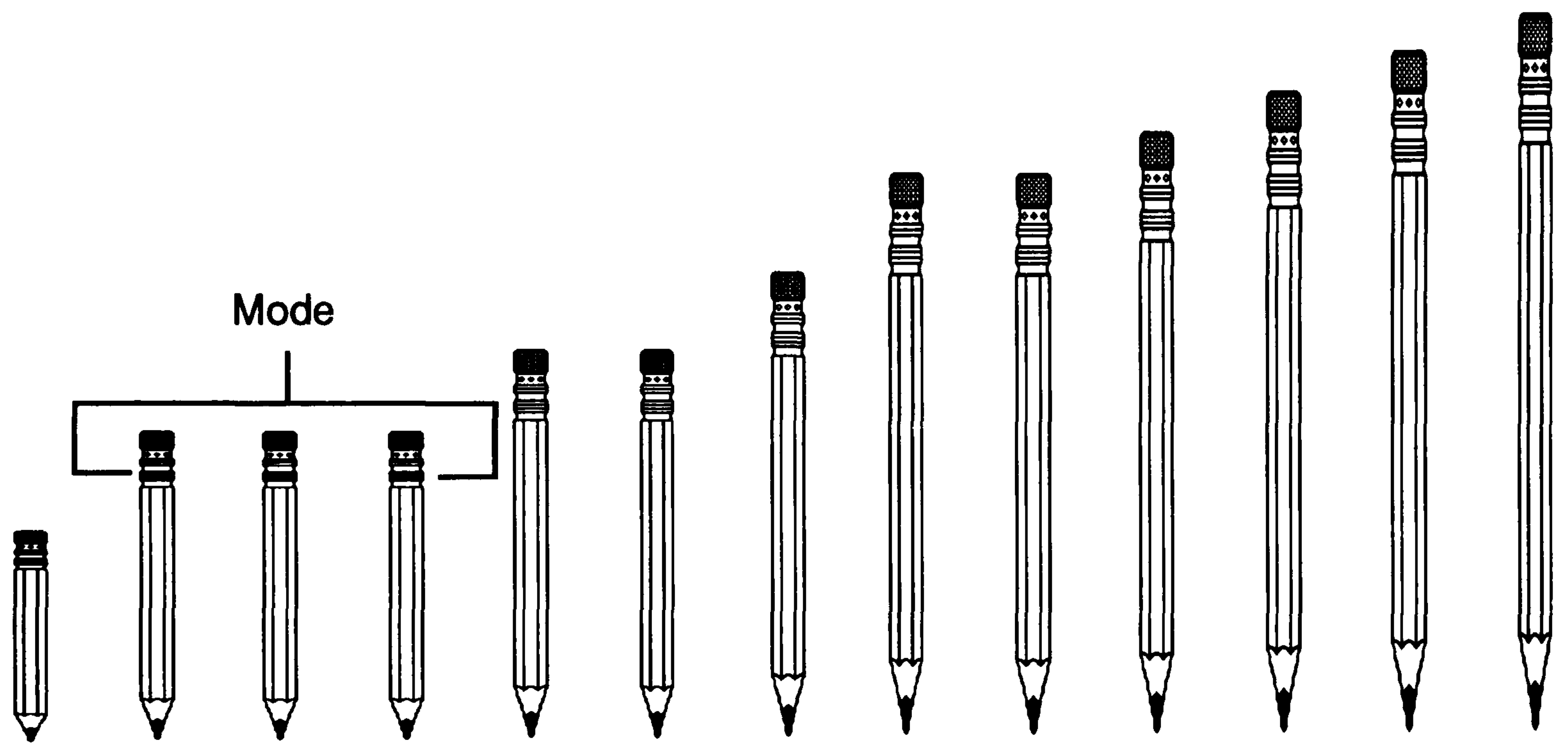
- The following data represent the number of hours worked in each day in a two-week period. What is the mode?

8	7	9	6	8	10	9
9	5	6	7	9	8	9

- Because it occurs most often, 9 is the mode.

Measures of Central Tendency

The Mode



Measures of Central Tendency

The Median

Definition:

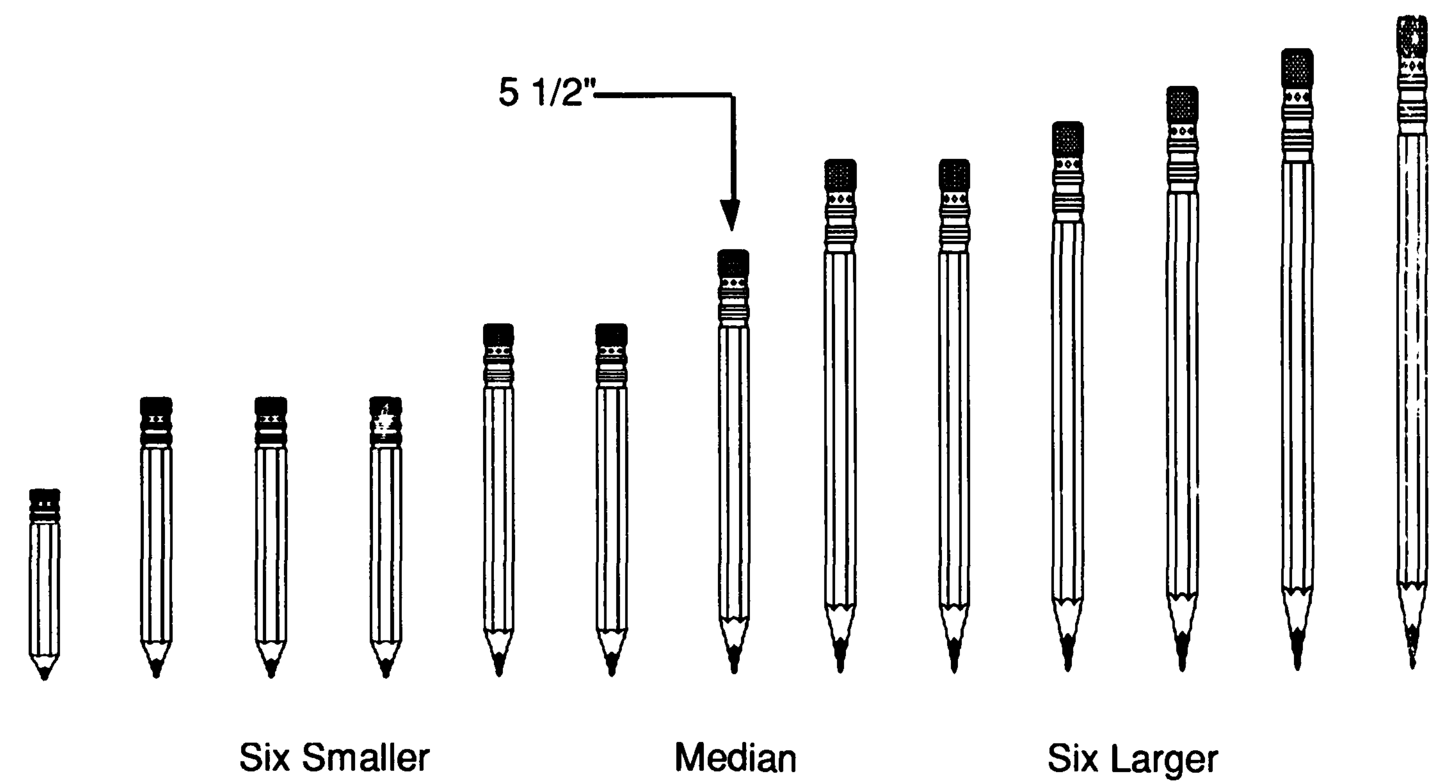
The number that splits a data set in two parts such that an equal number of points falls above and below that number.

Method:

1. Arrange data in ascending order.
2. Calculate rank of the median = $(n + 1)/2$.
3. Select the data point in rank position.

Measures of Central Tendency

The Median



Measures of Central Tendency

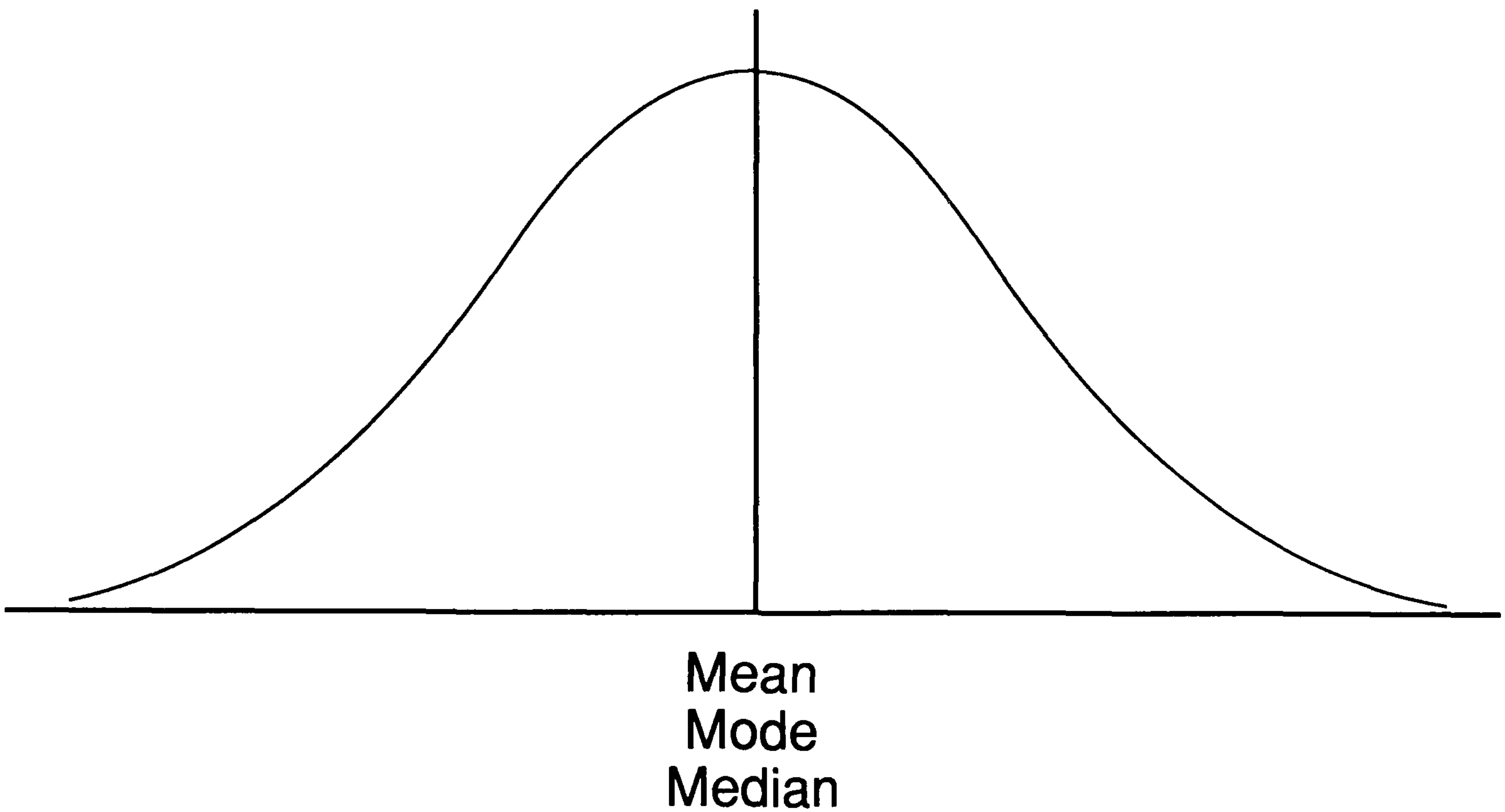
Final Points and Reminders

- Each measure of central tendency has advantages and disadvantages.
- Use the measure(s) of central tendency that best reflect(s) the nature of your data.
- Whenever possible, represent the data using all the measures of central tendency.
- Know your data.

EXERCISE 3-2

CALCULATING THE MEAN, MODE, AND MEDIAN

Normal Distribution



Measures of Variation

The Range

The range is equal to the largest value in the data set minus the smallest value in the data set.

Advantage:	Easy to calculate and understand
Disadvantage:	Does not reveal information about how values in between are dispersed

Measures of Variation

Standard Deviation

$$\sigma = \sqrt{\frac{\sum (x - \mu)^2}{n}}$$

x = value of a particular data point

$\mu = \dfrac{\sum x}{n}$ = mean (average) of data points

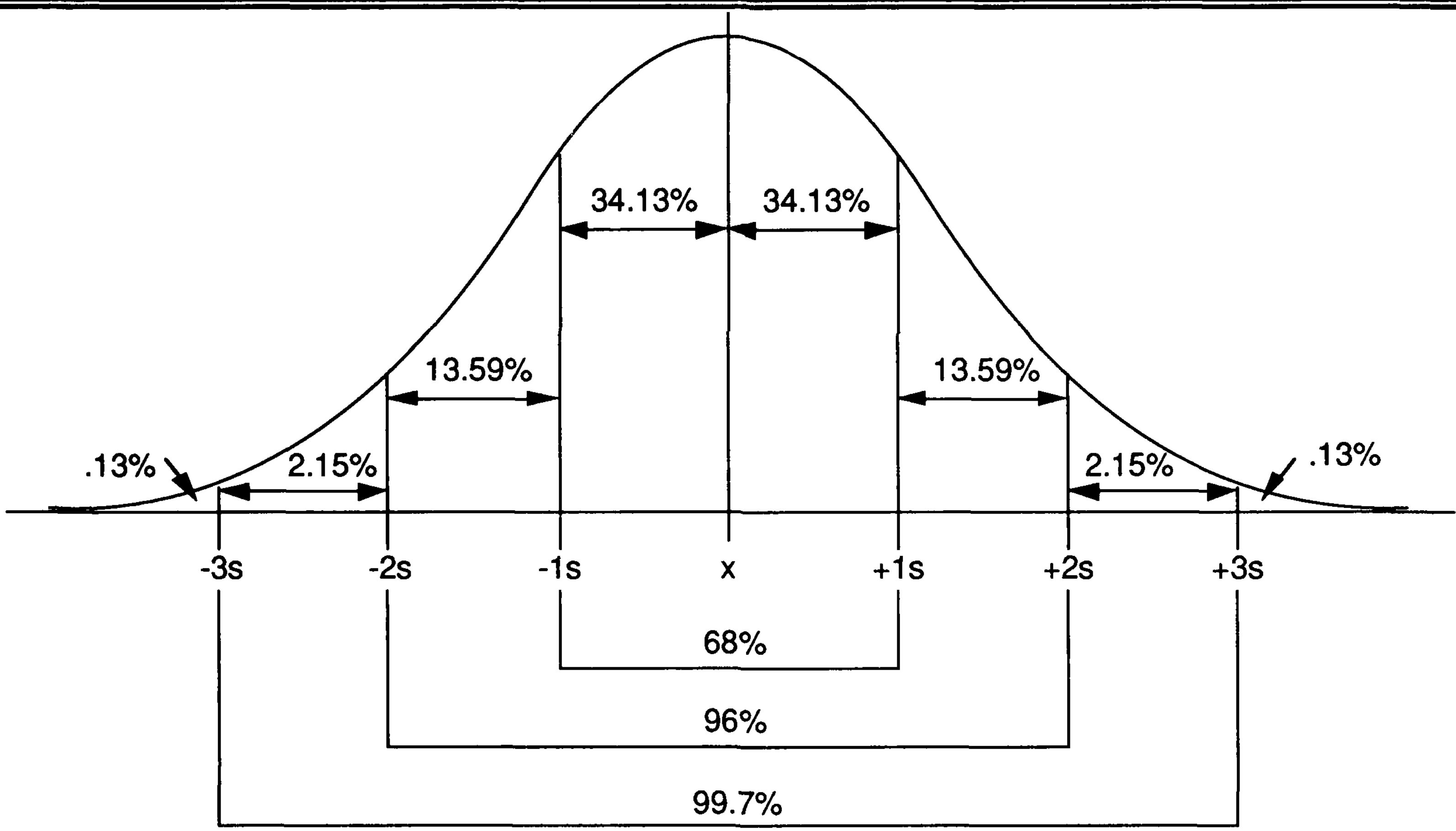
n = number of data points

Measures of Variation

Standard Deviation of
Small Sample Sizes
($n \leq 30$)

$$s = \sqrt{\frac{\sum (x - \mu)^2}{n - 1}}$$

Normal Distribution & the Standard Deviation



Exercise 3-3

CALCULATING THE STANDARD DEVIATION

Sampling

What Is Sampling?

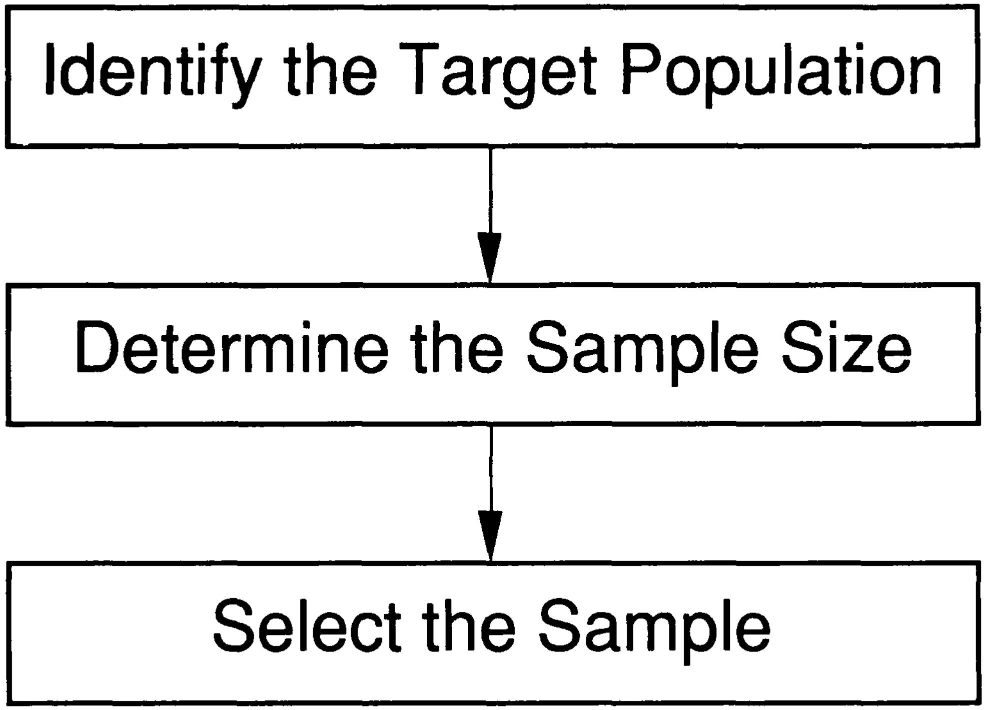
Selection of representative elements from a target population to gain information about the entire target population

Why Use Sampling?

- Target population too large
- Target population geographically separated
- Save time and money

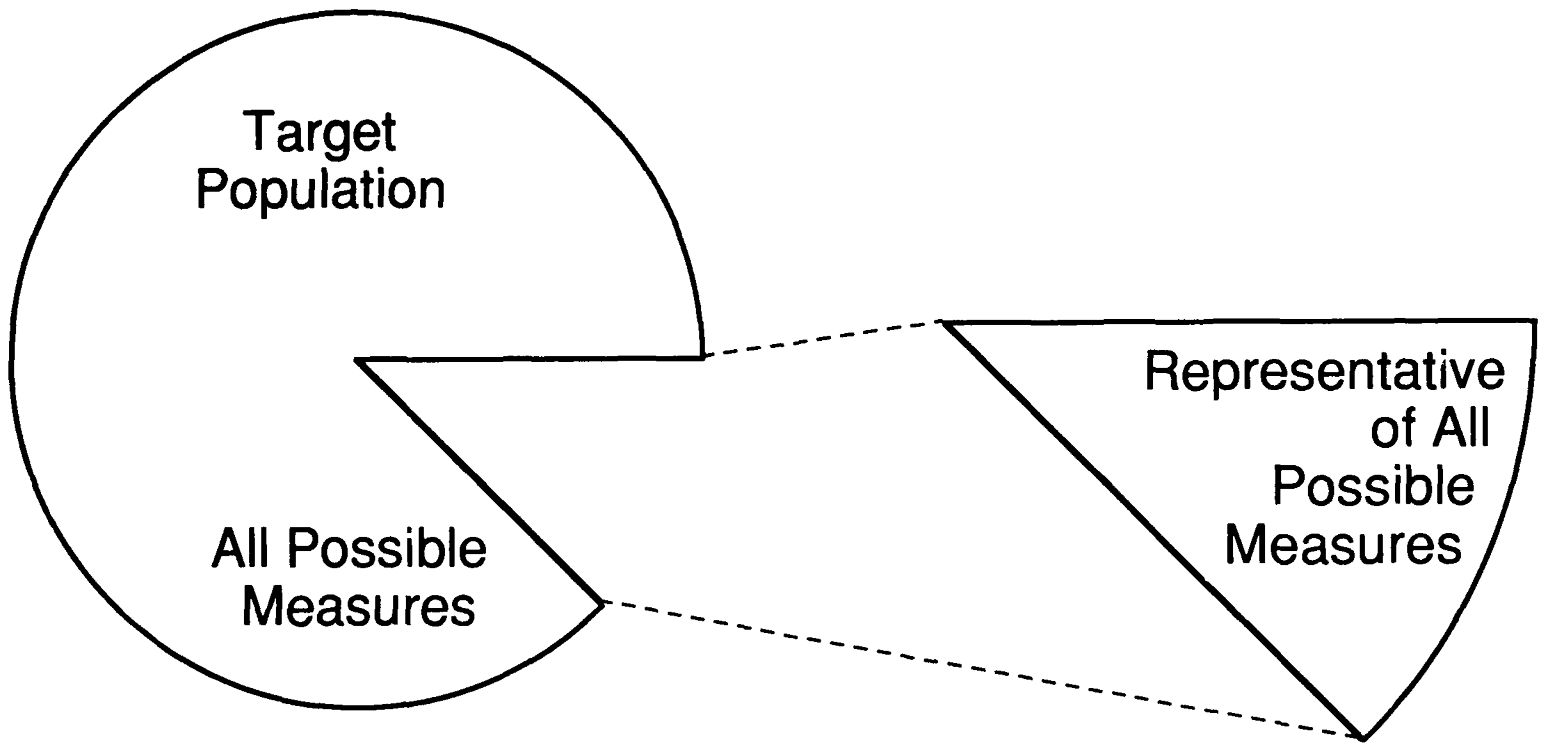
Sampling

Sampling Procedure



Sampling

Sample Size



Sampling

Sampling Techniques

- **Random Sample**
- **Stratified Sample**
- **Cluster Sample**

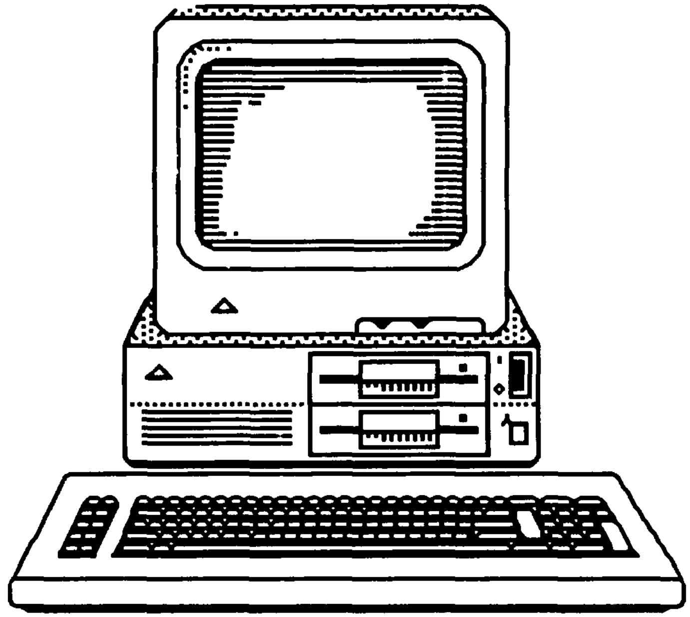
Sampling

Random Sampling

Random Numbers Table

54463	96754
15389	34357
85941	06318
61149	62111
05219	47534
41417	98614
28357	24856
17783	24856
177783	96887
40950	90801
82995	55165

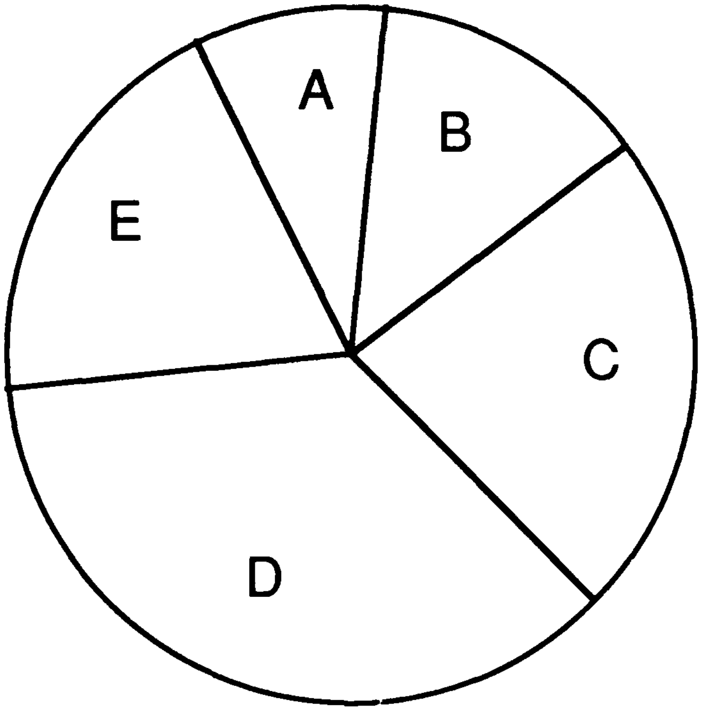
Computer Generated



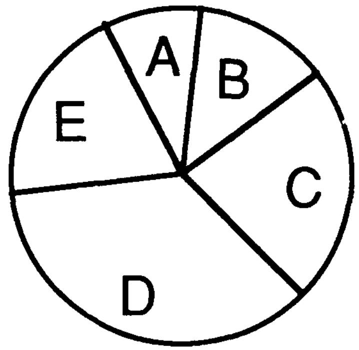
Sampling

Stratified Sampling

Target Population

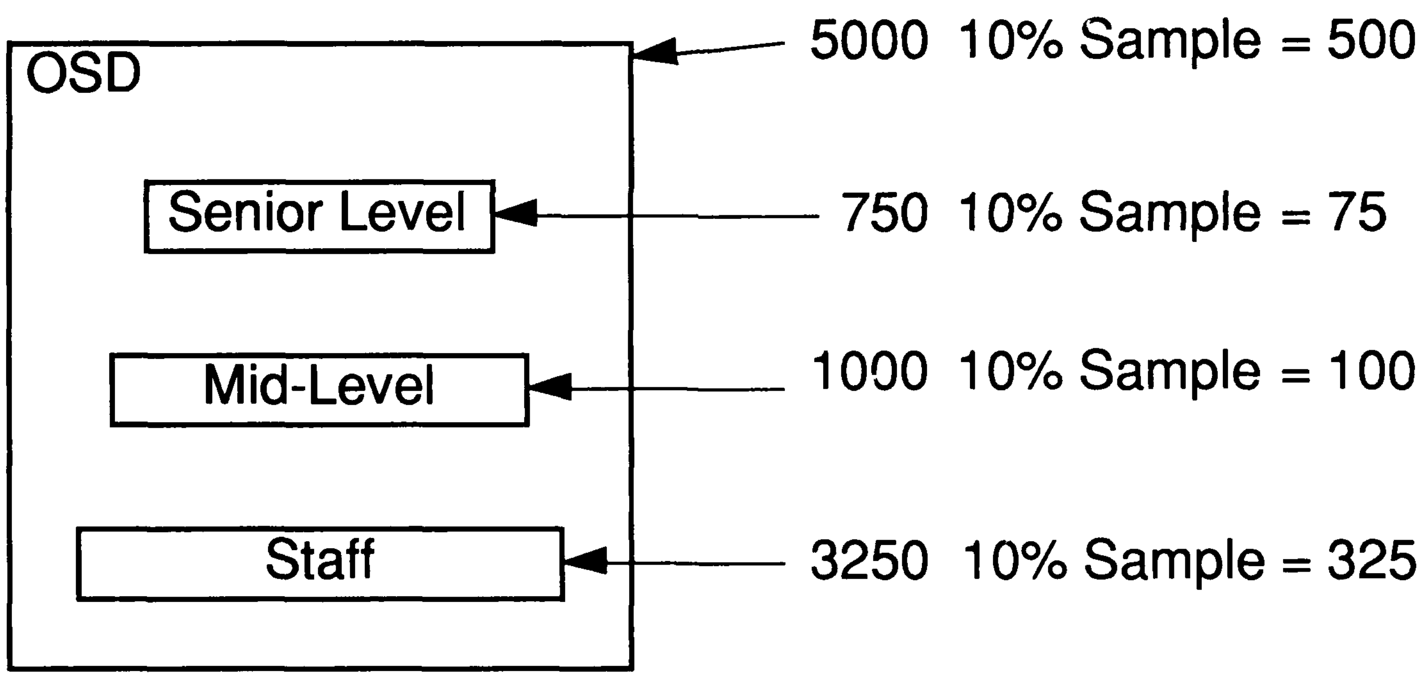


Stratified Sample



Sampling

Stratifed Sampling



Sampling

Cluster Sampling

- Groups are selected at random.
- All group members/test items are used.

MODULE FOUR

PLANNING AND DOING:

FLOW CHARTING AND CAUSE AND EFFECT DIAGRAMMING

Module Four Objectives

Upon completion of this module, participants will be able to:

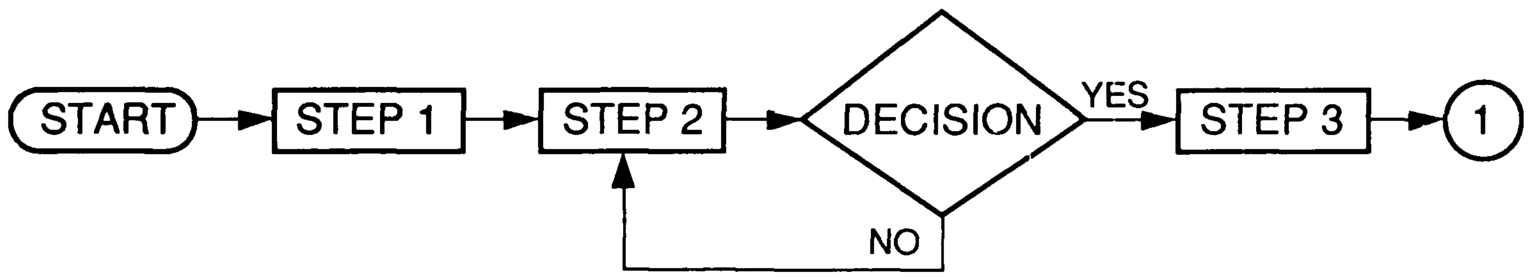
- Describe the technique of flow charting a process.
- Apply flow charting to a DoD process.
- Describe the technique of cause and effect diagramming.
- Apply cause and effect diagramming to a DoD process.

What is a Flow Chart?

FLOW CHART:

A diagram of the steps in a process and their interrelationships.

What is a Flow Chart?

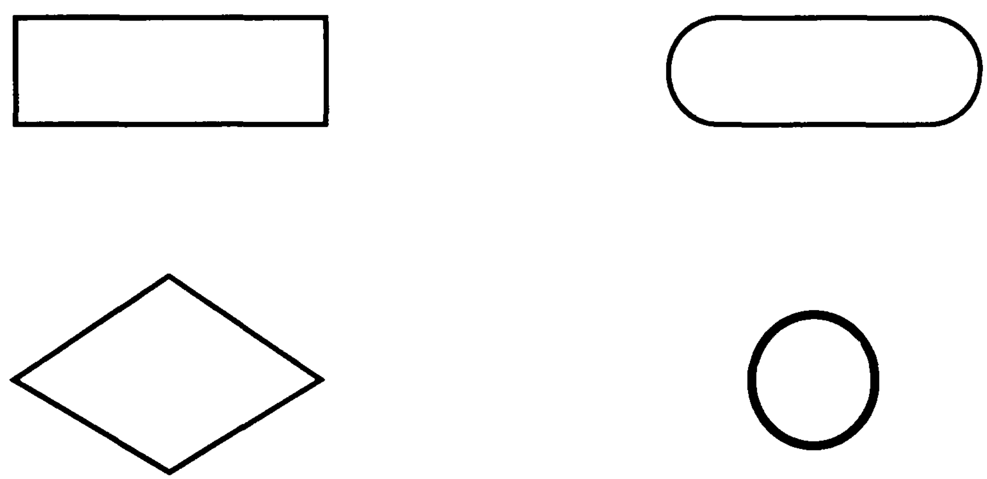


Benefits of Flow Charting

- **A flow chart can help you:**
  - Determine the steps in a process and better understand their interrelationships.
  - Identify unnecessary steps or inefficiencies.
  - Identify the differences between how a process <u>should</u> work and how it <u>does</u> work.
  - Target specific areas for process improvement.

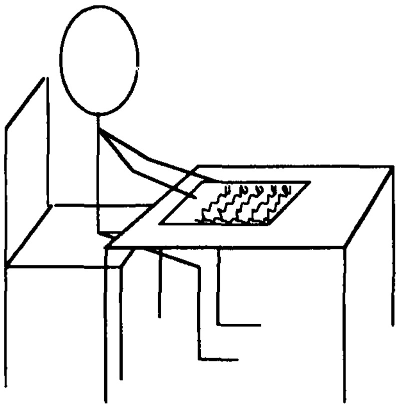
Creating a Flow Chart

- Flow charts do not need to be complicated.
- As few as four symbols can be used to create a good flow chart:

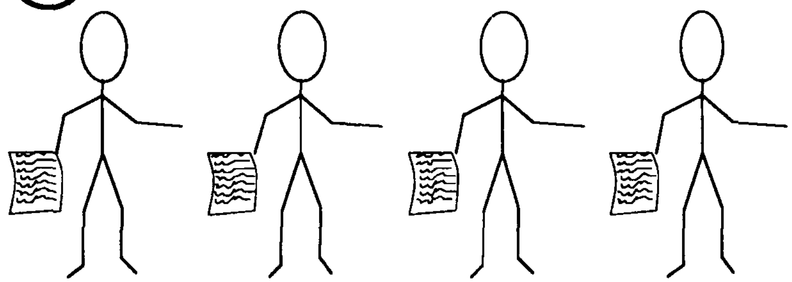


Applying Flow Charting

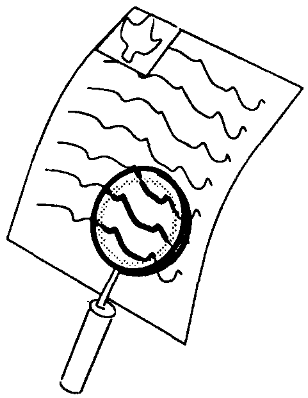
1



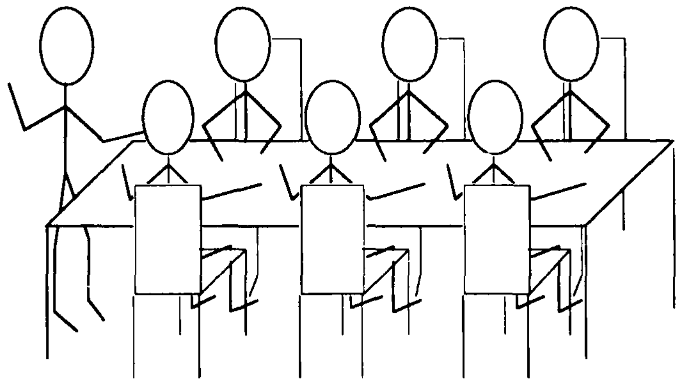
2



3



4



Creating a Flow Chart

Process Flow Worksheet

#	Step Description	Symbol

#	Step Description	Symbol

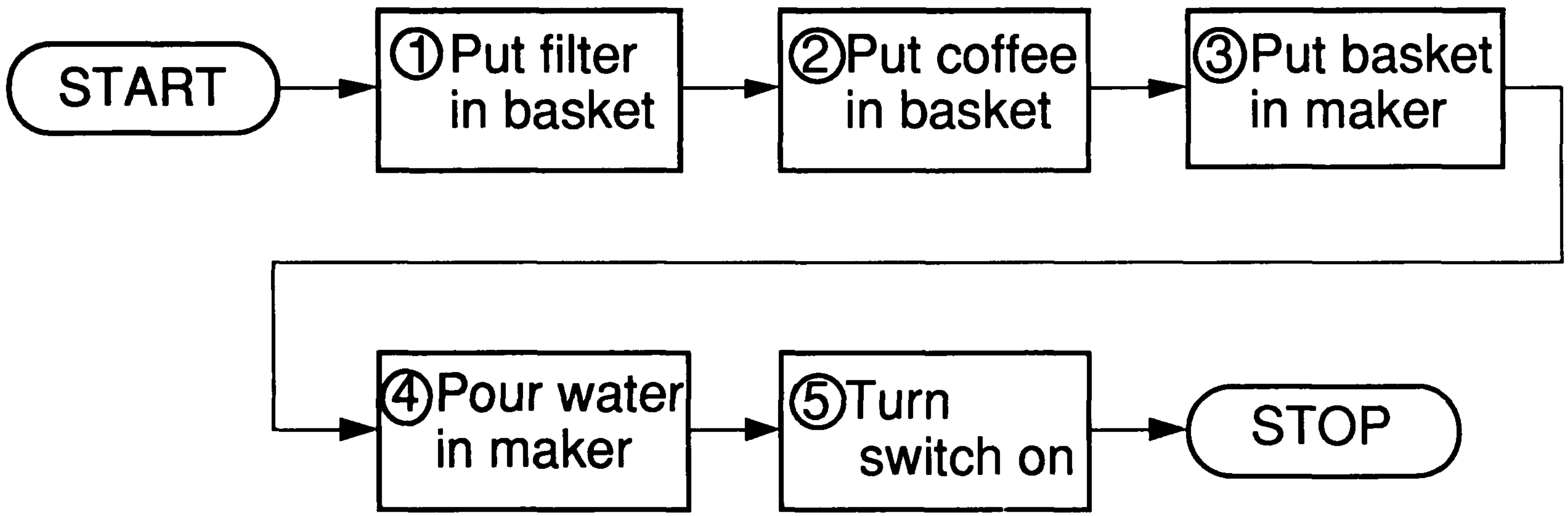
Exercise 4-1

Flow Charting a Process

Applying Flow Charting

Macro Flow Chart

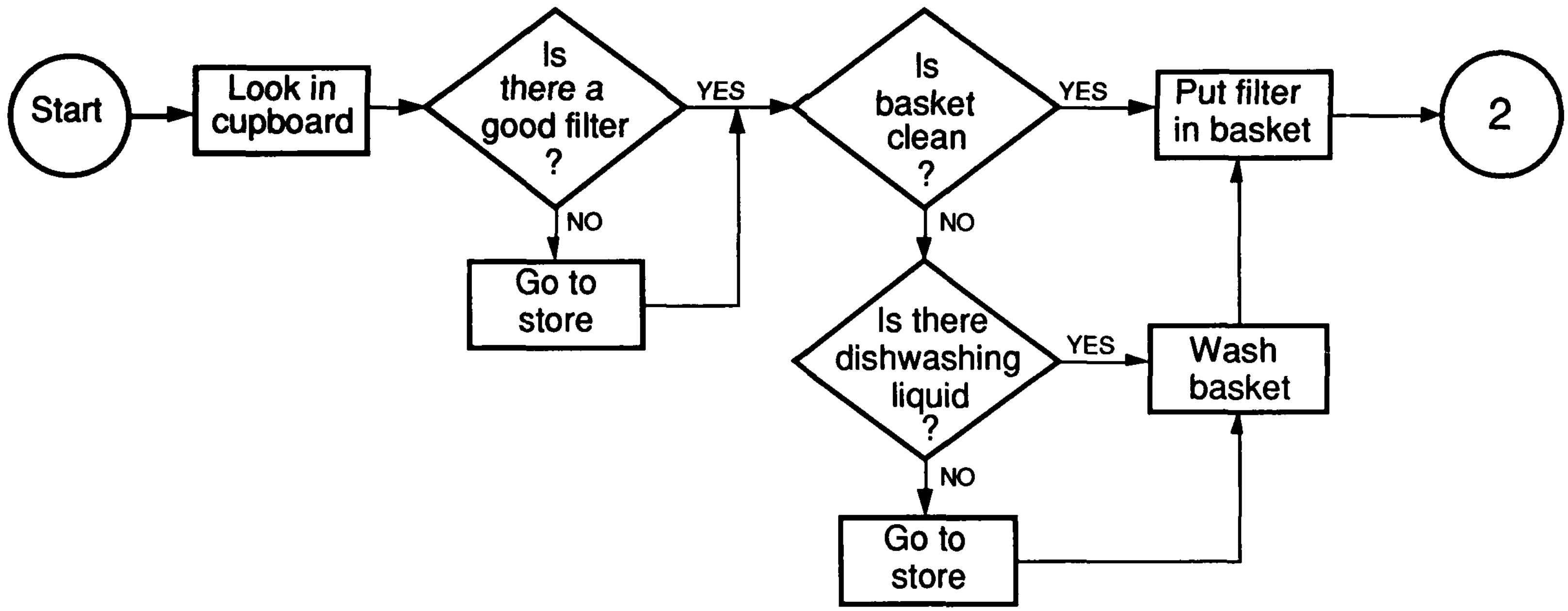
Making Good Coffee



Applying Flow Charting

Micro Flow Chart

Step 1: Put Filter in Basket



Exercise 4-2

Flow Charting a DoD Process

Applying Flow Charting

Final Points and Reminders

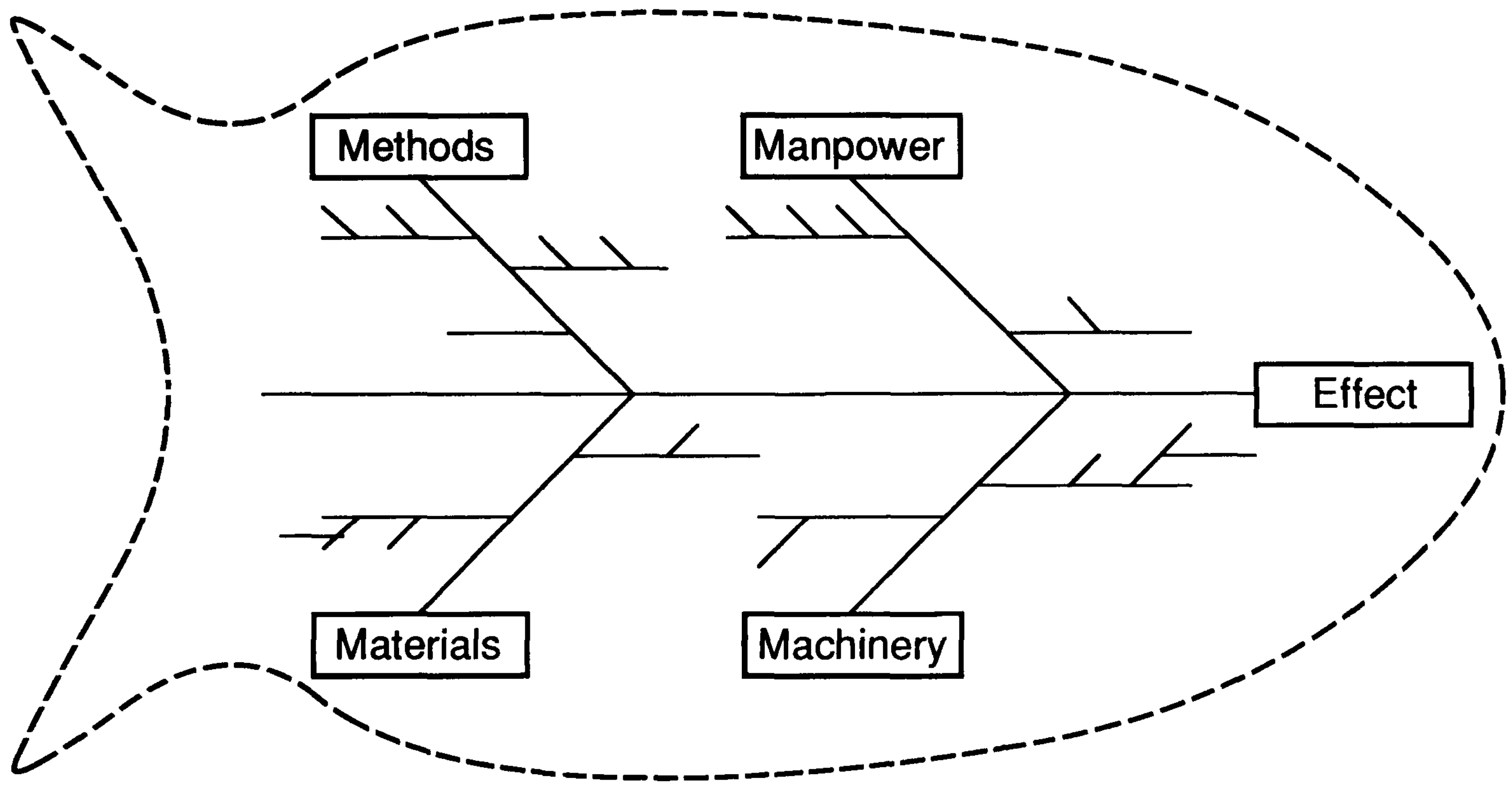
- Computer programs are very useful for flow charting.
- It is beneficial to flow chart processes that appear to be working well.
- Flow charts help eliminate the perception that processes are working as they should.
- Flow charts are an excellent tool for pointing out nonproductive work.

What is a Cause and Effect Diagram?

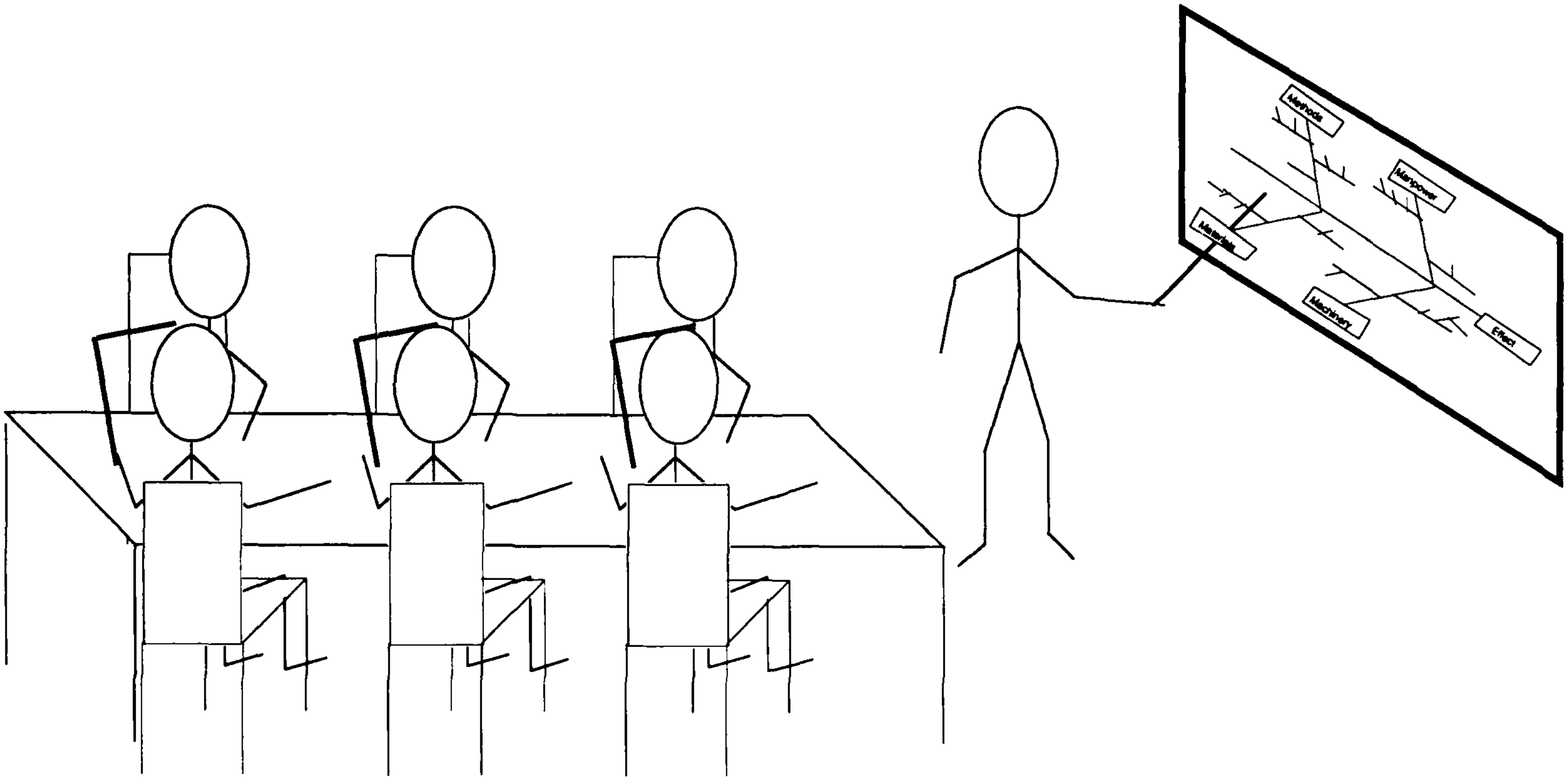
CAUSE AND EFFECT DIAGRAM:

A graphic representation of the relationships between some "effect" and the <u>possible</u> causes of that "effect."

What is a Cause and Effect Diagram?

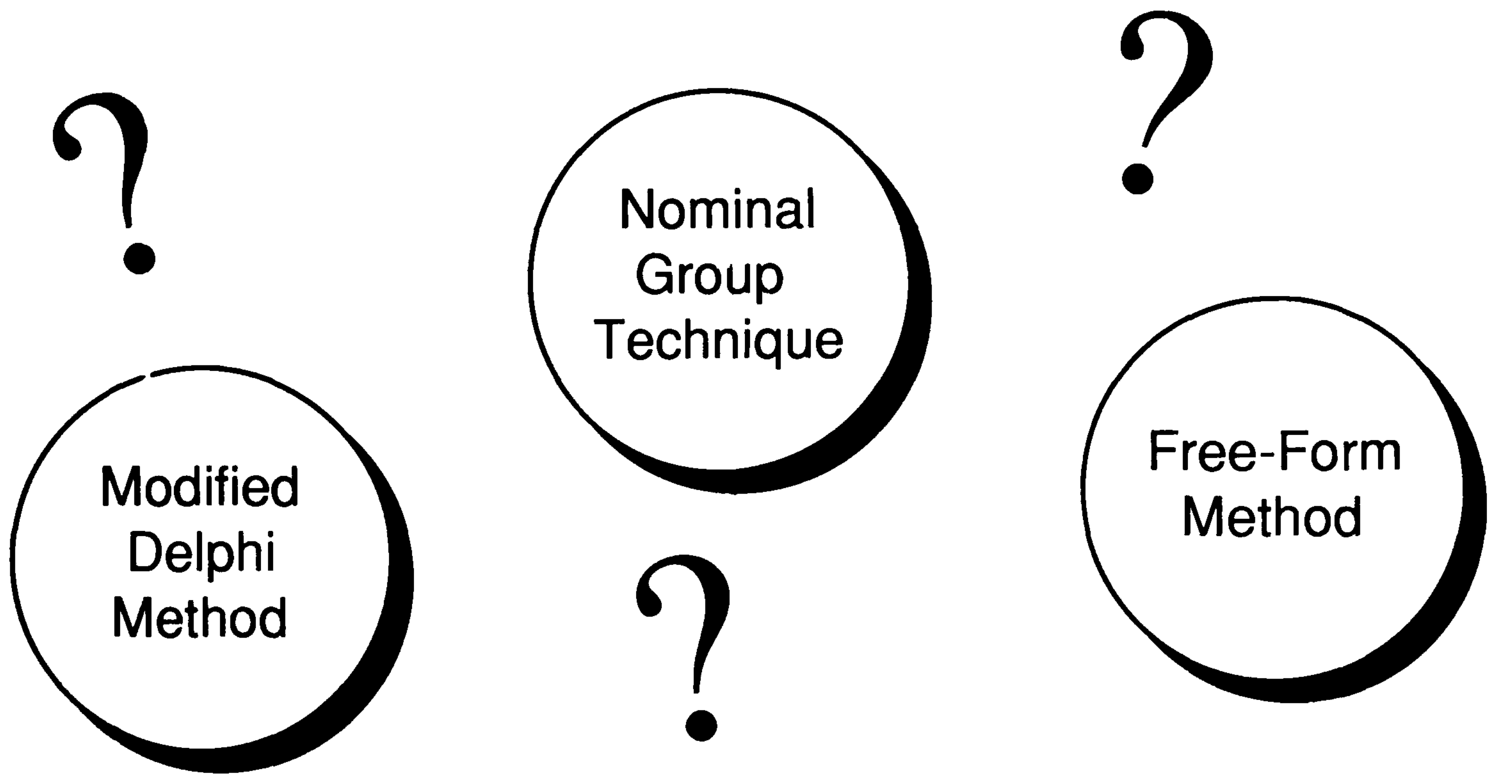


Applying Cause and Effect Diagramming



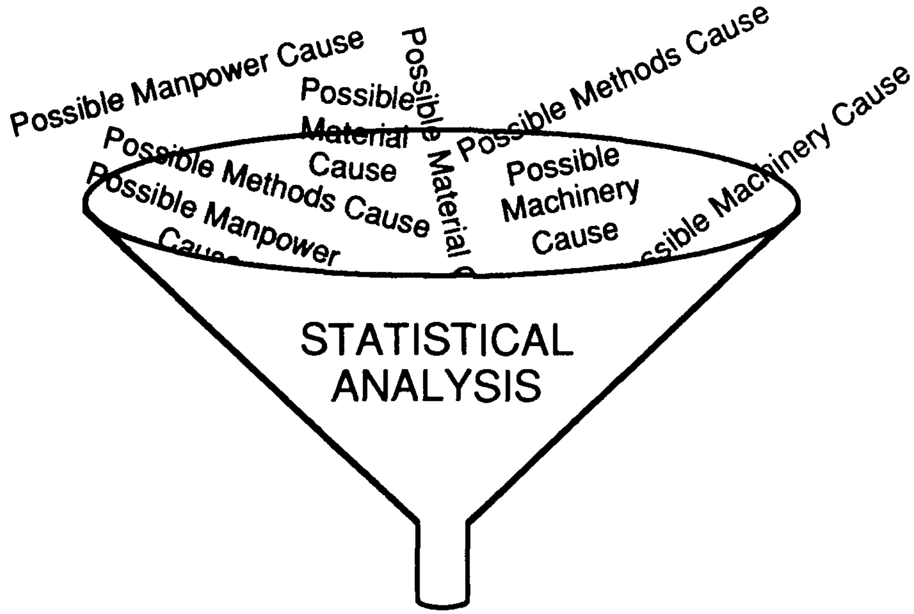
Applying Cause and Effect Diagramming

Brainstorming Techniques



Applying Cause and Effect Diagramming

Possible Causes



Identified Causes

1. Method Cause
2. Manpower Cause
3. Material Cause

Exercise 4-3

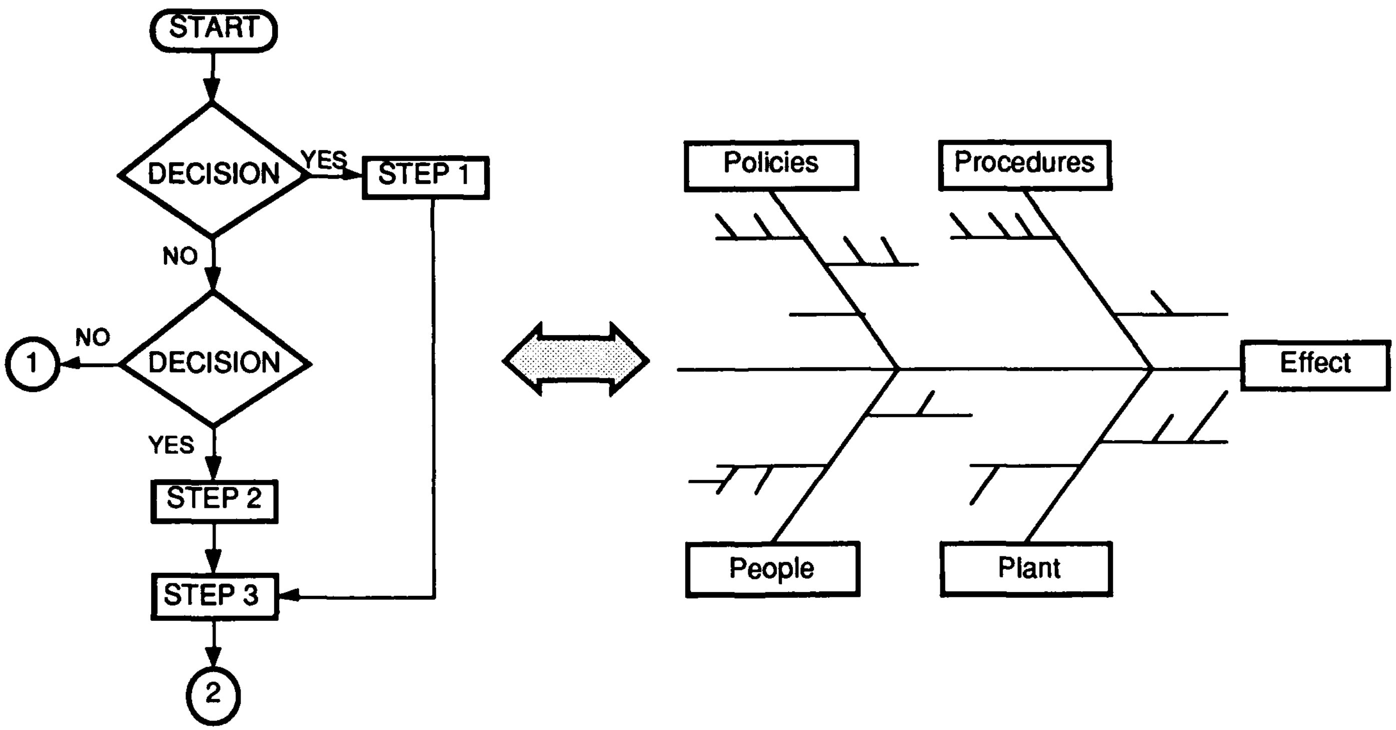
Creating a Cause and Effect Diagram

Exercise 4-4

Applying Cause and Effect Diagramming to a DoD Process

Applying Cause and Effect Diagramming

Identifying Effects for Analysis



Applying Cause and Effect Diagramming

Final Points and Reminders

- An effect statement should be an unambiguous, unsuggestive description of a problem or situation.
- Cause and effect diagramming generates <u>potential</u> causes of an effect.
- Potential causes must be analyzed statistically to identify real causes.

MODULE FIVE

CHECKING AND ACTING:

CHECK SHEETS, PARETO CHARTS, HISTOGRAMS, AND SCATTER DIAGRAMS

Module Five Objectives

Upon completion of this module, the participant will be able to:

- Construct and apply check sheet methodology to record and process data.
- Explain the design concept of a Pareto chart.
- Display DoD type data *in a Pareto chart and interpret the results.*
- Explain the design concept of a histogram.
- Compare and contrast Pareto charts and histograms.
- Display DoD type data in a histogram and interpret the results.
- Describe the design concept of a scatter diagram.
- Display DoD type data in a scatter diagram and interpret the results.
- Explain how check sheets, Pareto charts, histograms, and scatter diagrams are used in the Check step of the PDCA cycle.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

CHECK SHEETS

Check Sheets

<table>
<tr><th>Problem</th><th colspan="5">Week</th></tr>
<tr><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>Total</th></tr>
<tr><td>A</td><td>||||</td><td>||</td><td>|||</td><td>||||</td><td>13</td></tr>
<tr><td>B</td><td>$\cancel{||||}$</td><td>||</td><td>|||</td><td>$\cancel{||||}$</td><td>15</td></tr>
<tr><td>C</td><td>|</td><td>||</td><td>|</td><td>|</td><td>5</td></tr>
<tr><td>D</td><td>||</td><td>|</td><td>|</td><td>||||</td><td>8</td></tr>
<tr><td>Total</td><td>12</td><td>7</td><td>8</td><td>14</td><td>41</td></tr>
</table>

Check Sheet: Simple form that supplies factual data about how often certain events happen.

A DoD Example

Problem: Rejections of policy statements

Reasons for Rejections:

- Lack of supporting data
- Faulty logic; didn't reason from cause to effect
- Inappropriate terminology; too technical
- Inconsistent with aspects of existing policy
- Mechanical problems – spelling, format, grammar

A DoD Example

Reasons for Policy Statement Rejection

Deficiency	February			
	week 1	week 2	week 3	week 4
Lack of Supporting Data				
Faulty Logic				
Inappropriate Terminology				
Inconsistent with Existing Policy				
Mechanical Problems				

Benefits of Check Sheets

- Simple to Use
- Easy to Understand
- Time-efficient

Constructing a Check Sheet

Step 1 Define the Observation Parameters

↓

Step 2 Define the Time Period

↓

Step 3 Design a Clear and Effective Form

↓

Step 4 Collect the Data Honestly

Exercise 5-1

Developing a Check Sheet

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

PARETO CHARTS

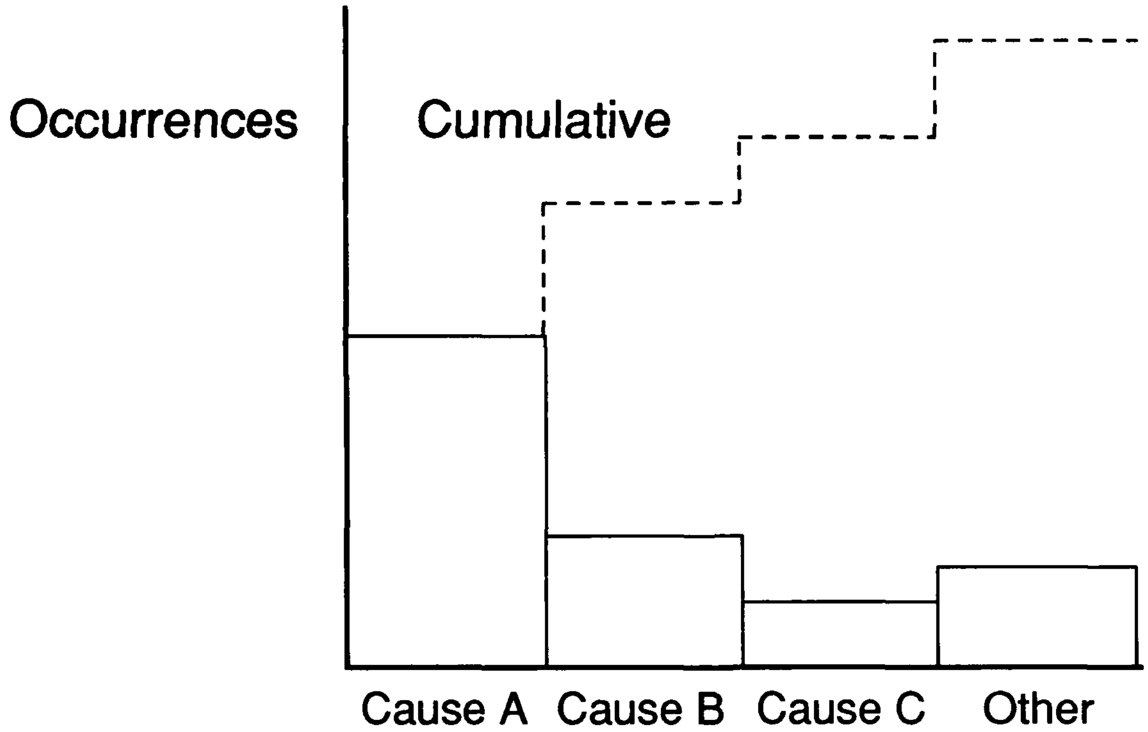
The Pareto Principle

The "Vital Few" and the "Trivial Many"

- The Pareto principle, or the 20-80 principle, states that 20% of the causes – the "vital few" – produce 80% of the results. The other 80% of the causes are the "trivial many," which produce only 20% of the results.

- As applied to the analysis of a process, the Pareto principle states that 20% of the problems are responsible for 80% of the cost of rework.

What is a Pareto Chart?



Pareto Chart: A vertical bar graph that presents "causes," or problems, in descending order of tneir impact on a given "effect."

Benefits of Pareto Charts

- We use Pareto analysis to distinguish the "vital few" from the "trivial many." This knowledge allows us to efficiently use our resources by attacking those problems with the greatest impact on the process.
- Pareto charts eliminate reliance on guesswork by providing information that allows us to determine which problems must be corrected.
- Pareto charts promote unity of effort by clearly illustrating which problems are most serious.

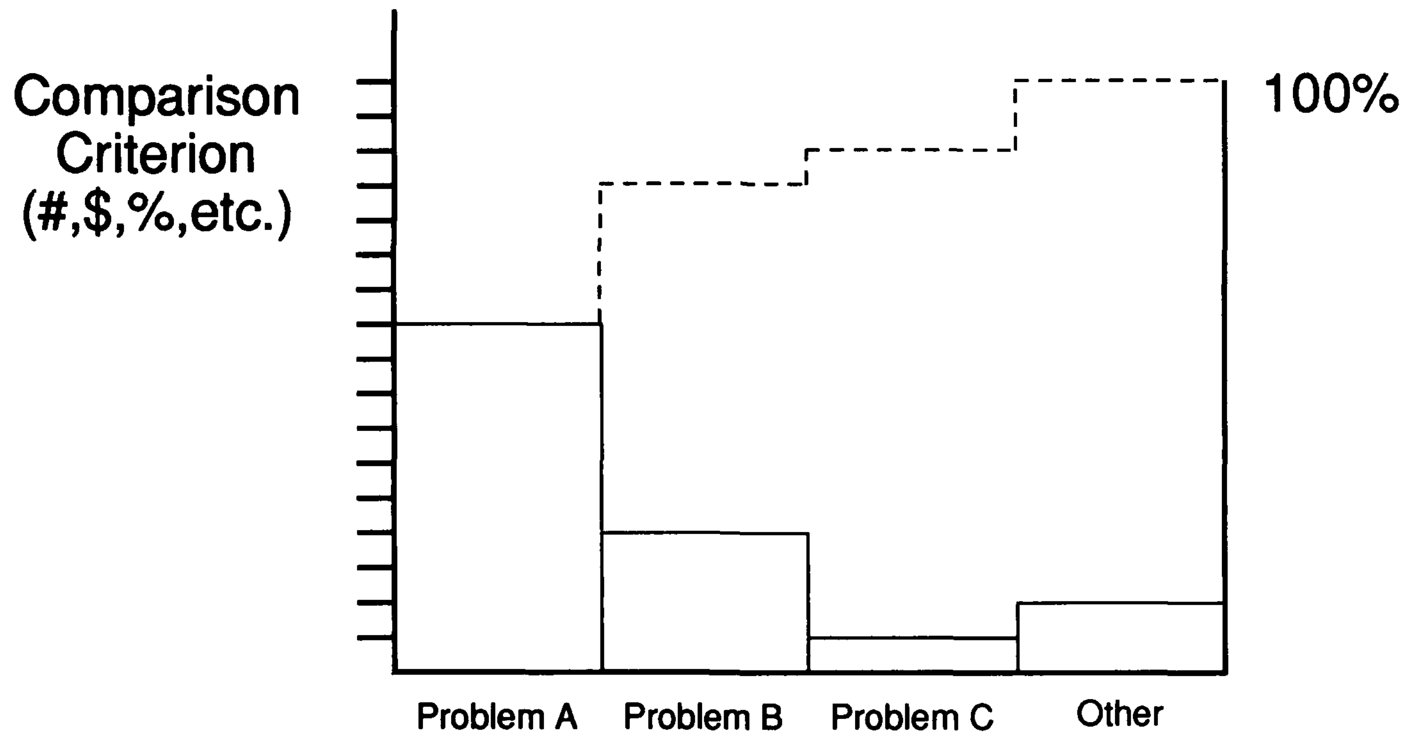
Choosing the Comparison Criterion

Problems in a Process

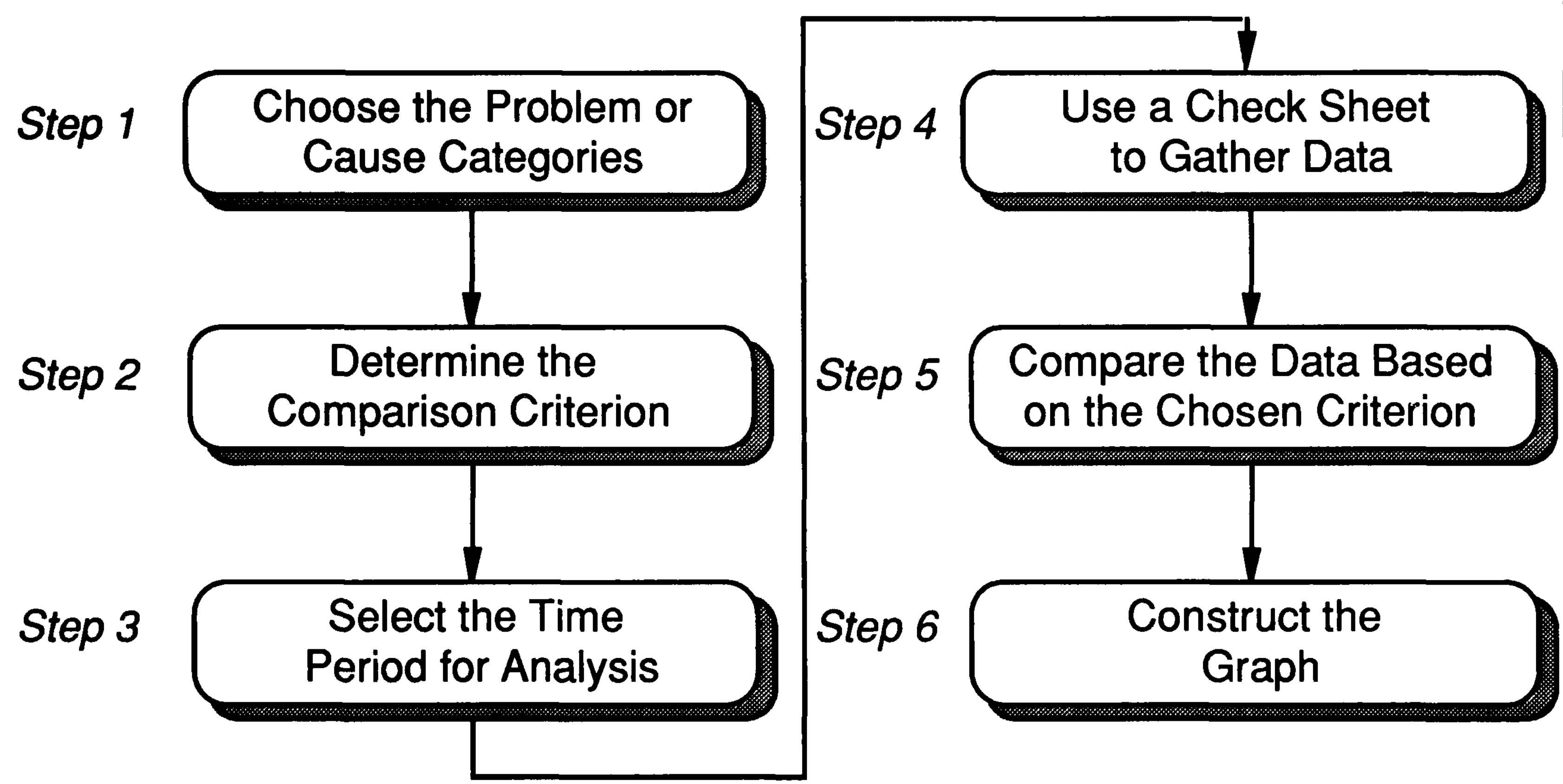
Problem	Frequency of Occurrence	Cost per Ocurrence	Total Cost
Problem A	100/month	$1.00	$100.00
Problem B	10/month	$1.00	$10.00
Problem C	2/month	$10,000.00	$20,000.00

- A comparison criterion is the measure that we use to rank the problems or causes being studied in a Pareto chart.
- Choosing the criterion is a critical step because different criteria may produce dramatically different results.

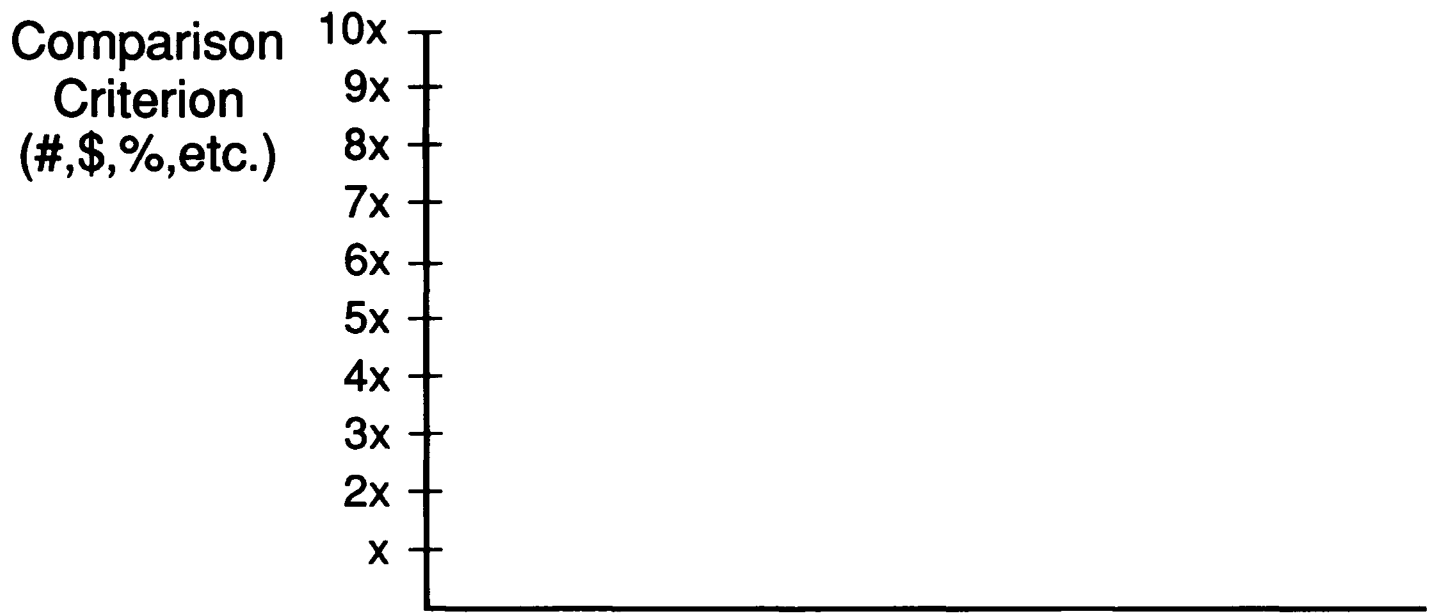
Structure of a Pareto Chart



Constructing a Pareto Chart

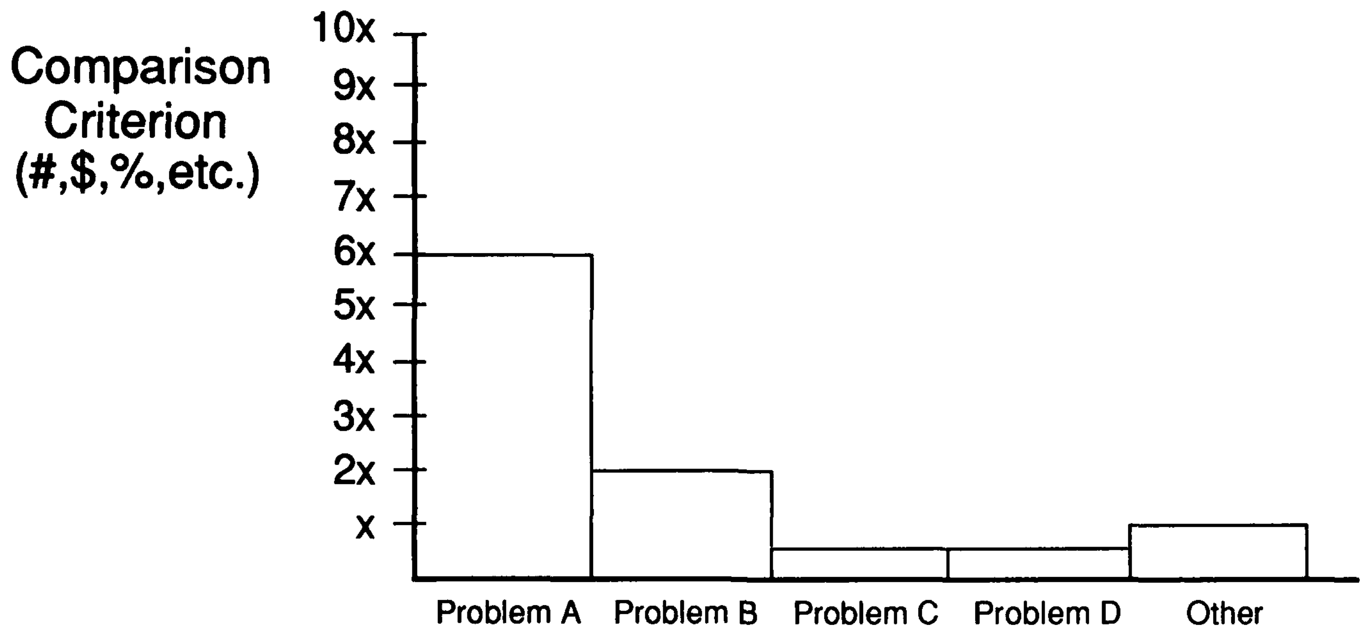


Constructing a Pareto Chart



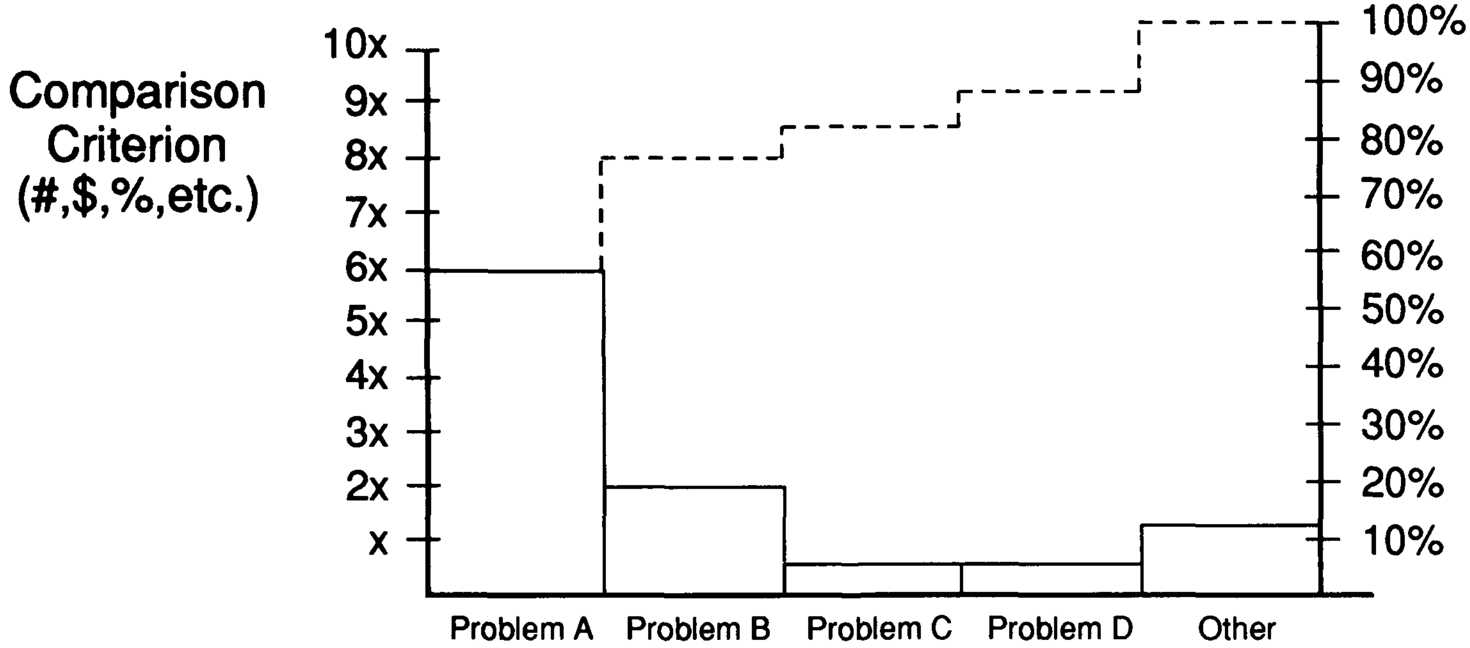
- Set up a graph with vertical and horizontal axes.
- Scale the vertical axis to reflect the comparison criterion.

Constructing a Pareto Chart



- List the problem categories from left to right along the horizontal axis.
- Draw rectangles for each problem category.

Constructing a Pareto Chart



- Draw a vertical axis on the right and scale it from 0% to 100%
- Draw the cumulative percentage line.

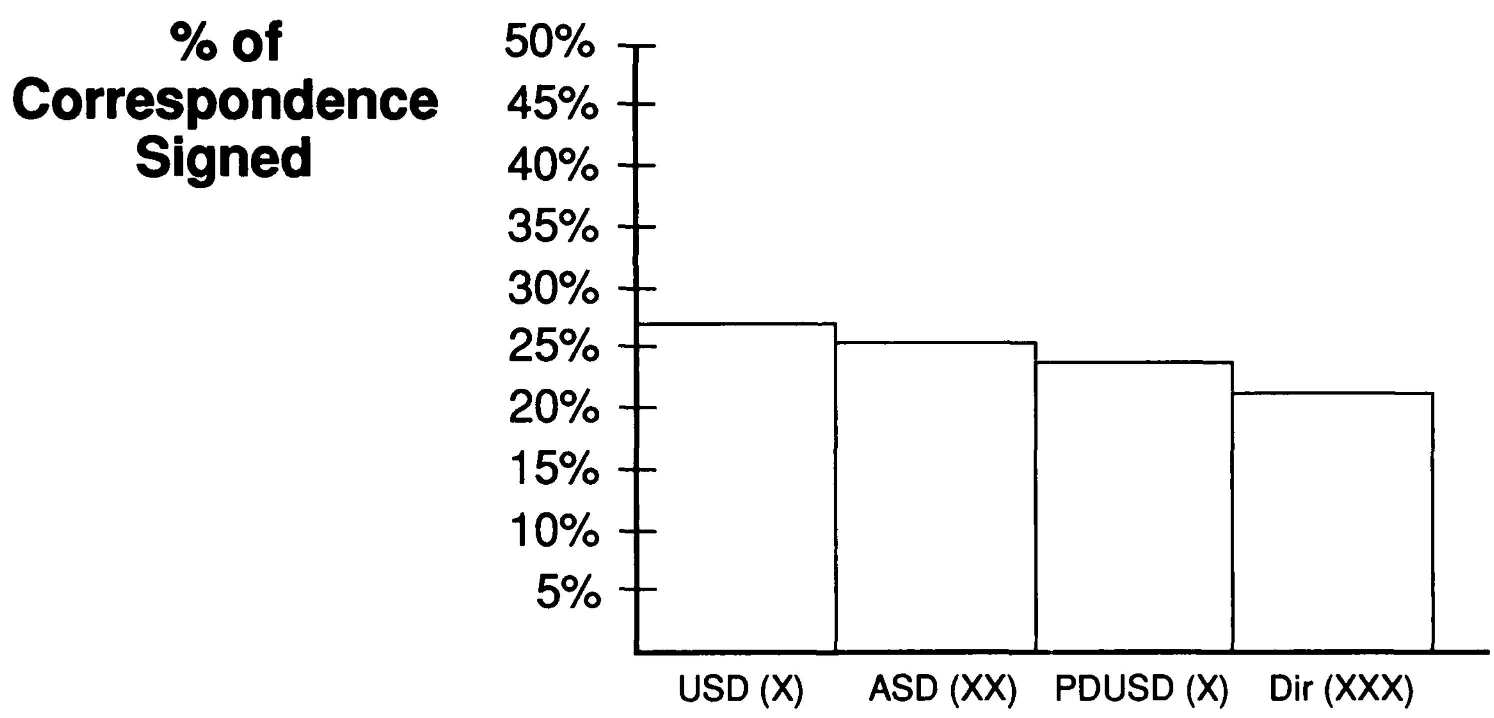
A Hypothetical DoD Example

The Paper Trail

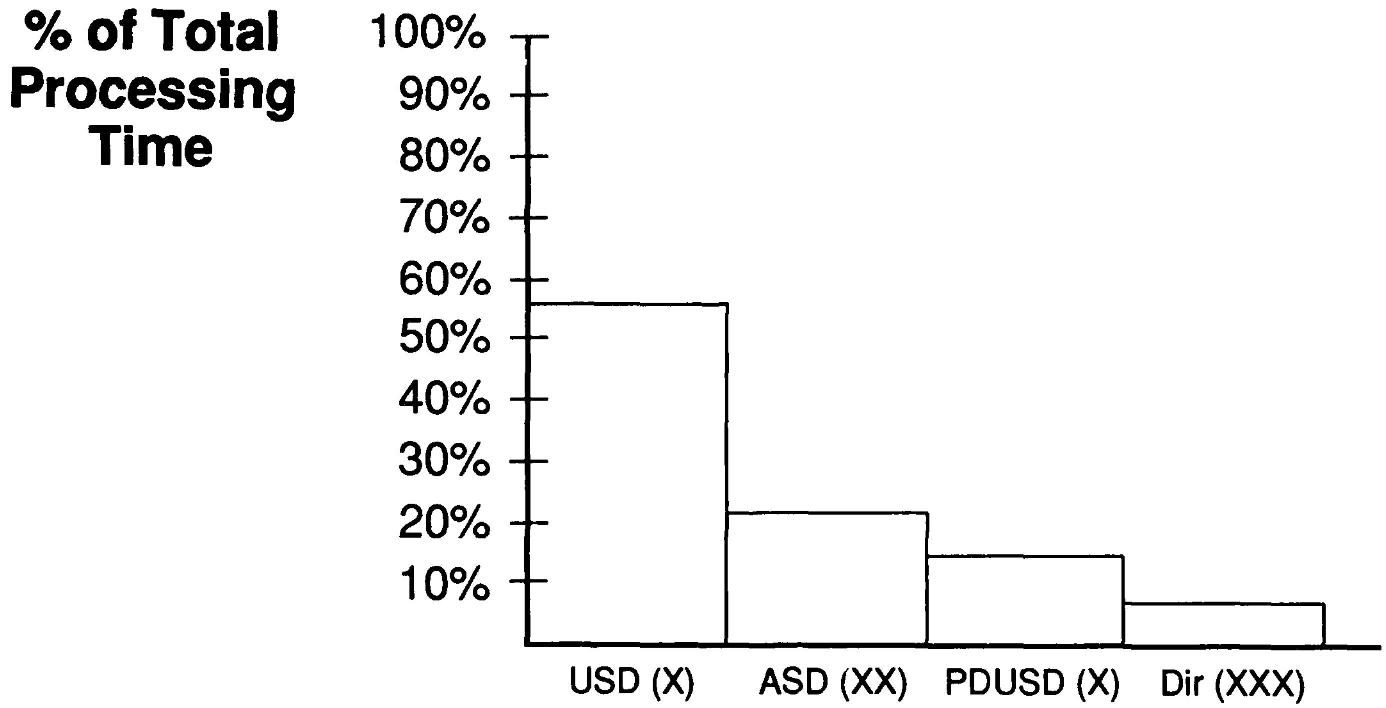
Office	1st Qtr	2nd Qtr	3rd Qtr	4th Qtr	Total Signatures	% of Signatures
USD (X)	125	125	125	125	505	27
PDUSD (X)	110	110	110	110	454	24
ASD (XX)	115	115	115	115	481	26
Dir (XXX)	91	91	91	91	417	22
Total:					1857	

- Table represents cumulative data from check sheets recording who signed correspondence during one year in all of USD (X).

A Hypothetical DoD Example



A Hypothetical DoD Example



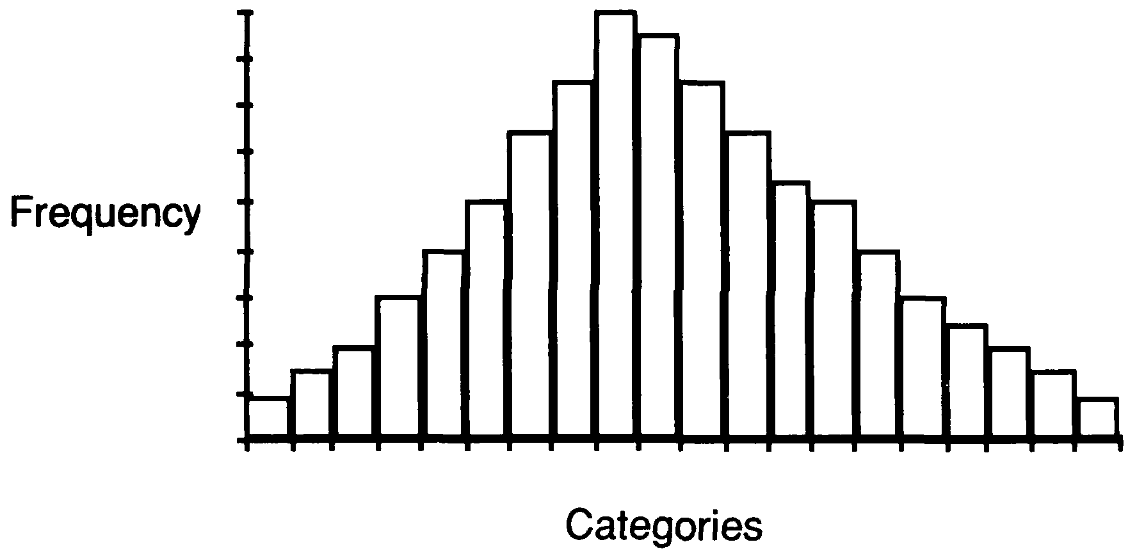
Exercise 5-2

Constructing a Pareto Chart

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

HISTOGRAMS

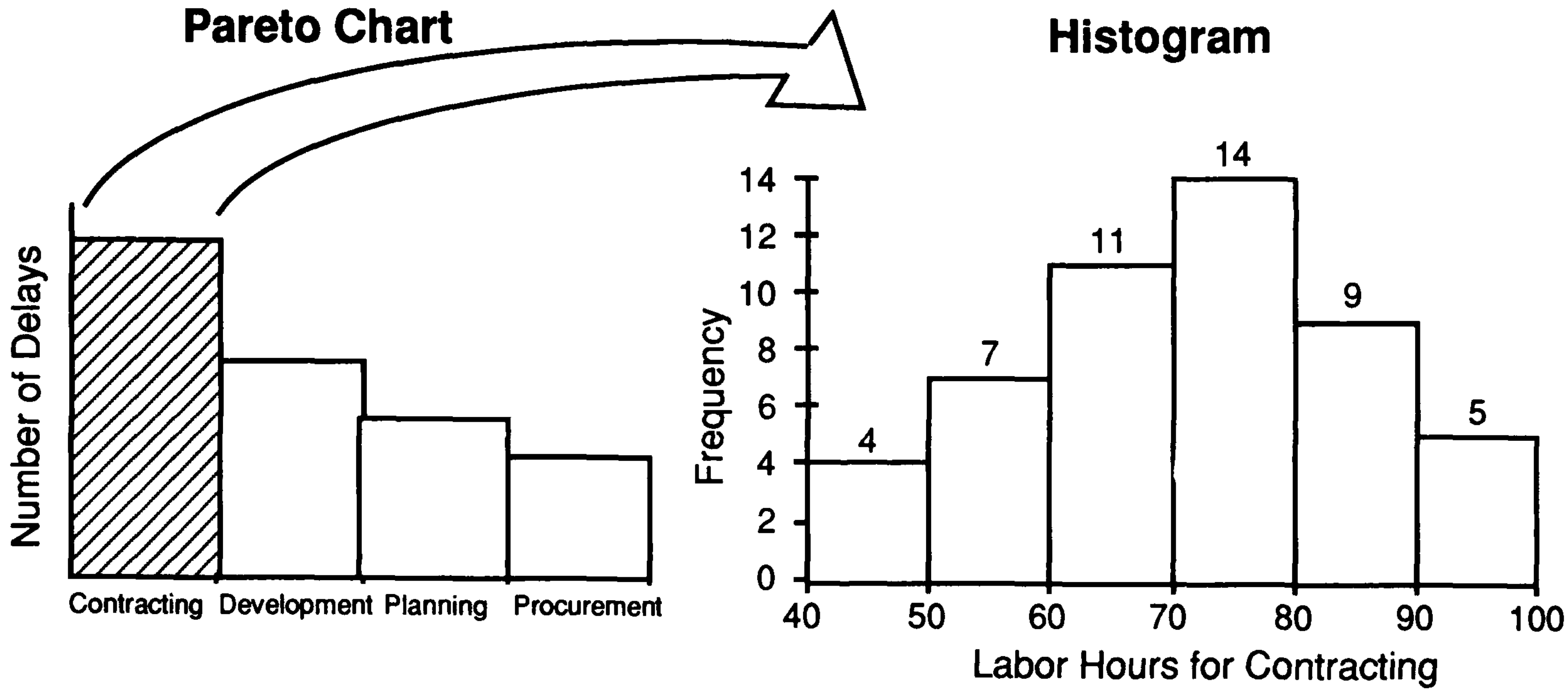
What is a Histogram?



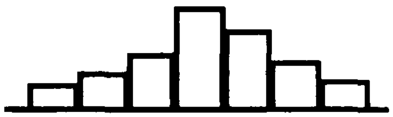
- Displays distribution of data with bars
- Shows amount of variation in a process
- Identifies sources of variation
- Summarizes, simplifies, and communicates data effectively

What is a Histogram?

Acquisition Process



How to Interpret a Histogram



Peaked (small variability)

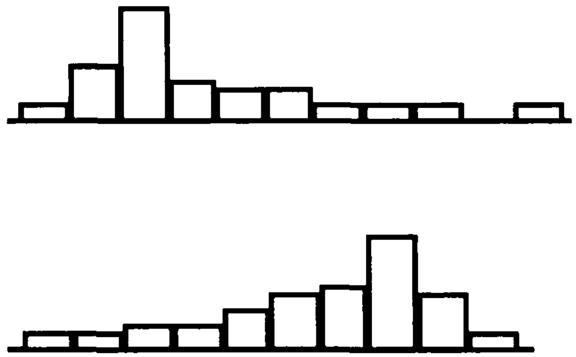
Less Peaked (large variability)

Peakedness

Measure of variability - how tall and skinny the distribution is

Skewedness

Measure of variability - how symmetrical the distribution is



Constructing a Histogram

Step 1 Identify and Define the Problem

↓

Step 2 Collect the Data

↓

Step 3 Prepare the Data

↓

Step 4 Construct the Graph

Constructing a Histogram

Step 3 Prepare the Data

a. Count the number of data points in the set of data.

b. Calculate the range for the entire data set.

c. Determine how many bars (class intervals).

d. Calculate the width of each bar.

e. Determine the boundaries and midpoints.

f. Construct a frequency table.

Constructing a Histogram

Step 3 Prepare the Data

Number of Labor Hours in Contracting Phase of Acquisition									
77	61	68	83	69	58	78	56	76	86
51	$\boxed{40}$	84	72	62	53	70	67	85	76
90	63	75	52	71	63	53	74	75	87
98	89	64	79	44	71	55	66	48	92
81	73	82	42	65	88	80	99	78	97

a. Count the number of data points in the data set. (50)

b. Calculate the range for the entire data set. (99 - 40 = 59)

Constructing a Histogram

Step 3 Prepare the Data

Number of Data Points	Number of Bars (Classes)
Under 50	5 - 7
50 - 100	6 - 10
100 - 250	7 - 12
Over 250	10 - 20

Number of bars = 6
Width = range/bars ≈ 10

c. Determine the number of bars (classes or intervals).

d. Calculate the width of each bar (class width).

Constructing a Histogram

Step 3 Prepare the Data

Class Number	Boundaries	Interval	Midpoint
1	39.5 - 49.5	40 - 49	44.5
2	49.5 - 59.5	50 - 59	54.5
3	59.5 - 69.5	60 - 69	64.5
4	69.5 - 79.5	70 - 79	74.5
5	79.5 - 89.5	80 - 89	84.5
6	89.5 - 99.5	90 - 99	94.5

e. Determine the boundaries and midpoints.

Constructing a Histogram

Step 3 Prepare the Data

Class Number	Boundaries	Interval	Midpoint	Frequency	Total
1	39.5 - 49.5	40 - 49	44.5	IIII	4
2	49.5 - 59.5	50 - 59	54.5	~~IIII~~ II	7
3	59.5 - 69.5	60 - 69	64.5	~~IIII~~ ~~IIII~~ I	11
4	69.5 - 79.5	70 - 79	74.5	~~IIII~~ ~~IIII~~ IIII	14
5	79.5 - 89.5	80 - 89	84.5	~~IIII~~ IIII	9
6	89.5 - 99.5	90 - 99	94.5	~~IIII~~	5
				TOTAL	50

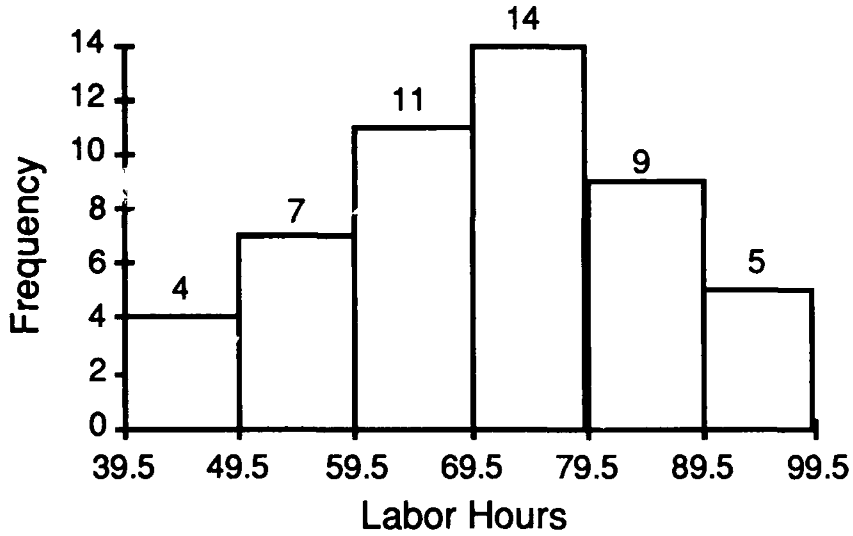
f. Construct a frequency table.

Constructing a Histogram

Step 4

Construct the Graph

Distribution of Labor Hours Required to Complete the Contracting Phase of Acquisition for Each Procurement



a. Mark and label the vertical scale.

b. Mark and label the horizontal scale.

c. Draw in the bars according to the frequency table.

d. Label the histogram.

Exercise 5-3

CONSTRUCTING A HISTOGRAM

Histogram Construction/Interpretation Tips

CONSTRUCTION

1. Use equal width intervals.
2. Don't use open intervals.
3. Don't make breaks in vertical or horizontal scales.
4. Be sure to select the proper number of intervals.
5. Keep the graph simple.

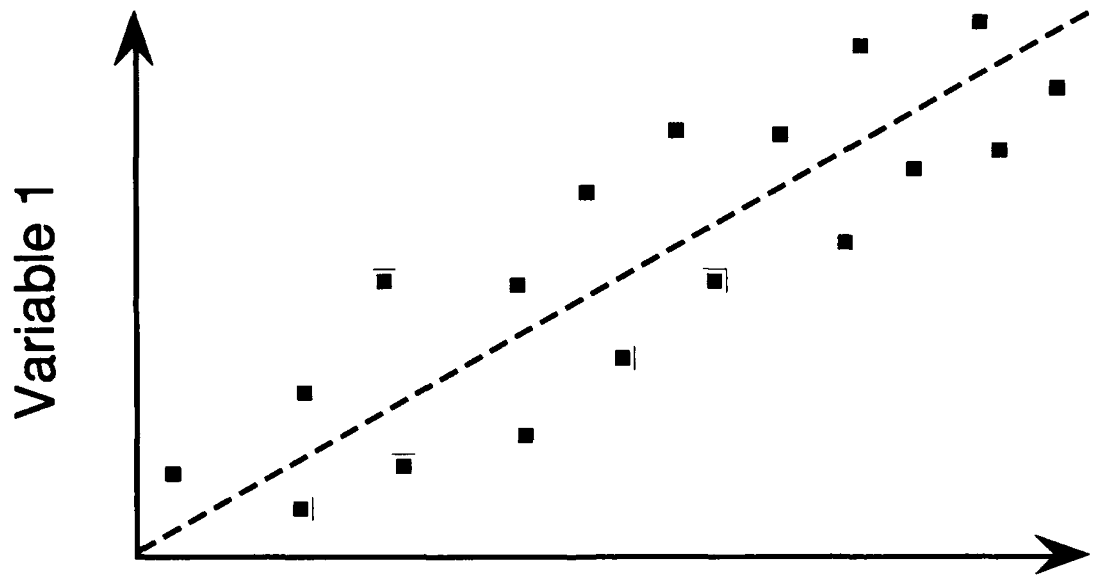
INTERPRETATION

1. Don't expect every distribution to follow a bell-shaped curve.
2. Be suspicious of accuracy of data if classes suddenly stop at one point without previous decline.
3. Look for twin peaks as indicator of data from two or more sources.

Check Sheets, Pareto Charts, Histograms, and Scatter Diagrams

SCATTER DIAGRAMS

What is a Scatter Diagram?



A scatter diagram shows the *relationship* between one variable and another.

What is a Scatter Diagram?

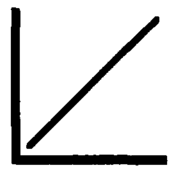
Examples of Variables that are Related:

- Quality and Productivity
- Number of Cars on the Key Bridge and Time of Day
- Quality and Customer Complaints
- Hemline and Economy

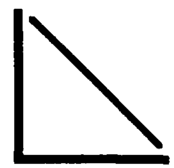
How to Interpret a Scatter Diagram

Types Of Correlations

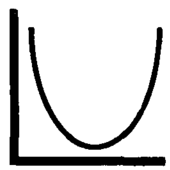
- POSITIVE



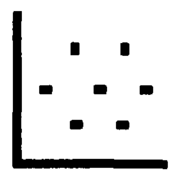
- NEGATIVE



- NONLINEAR

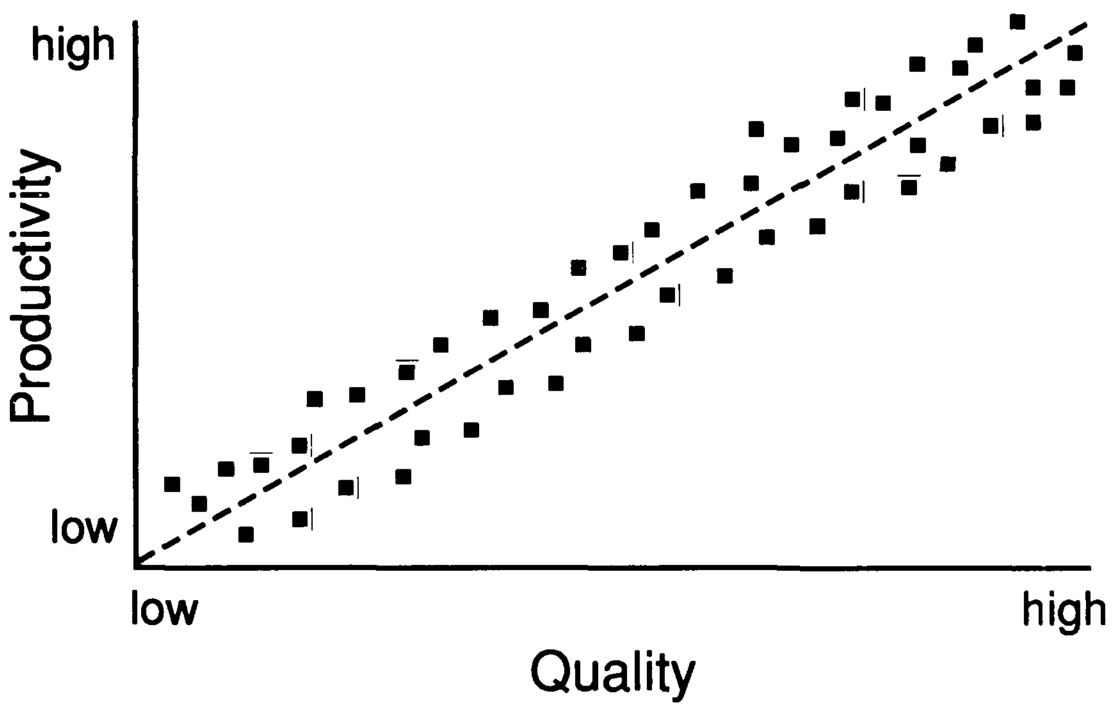


- NONE



How to Interpret a Scatter Diagram

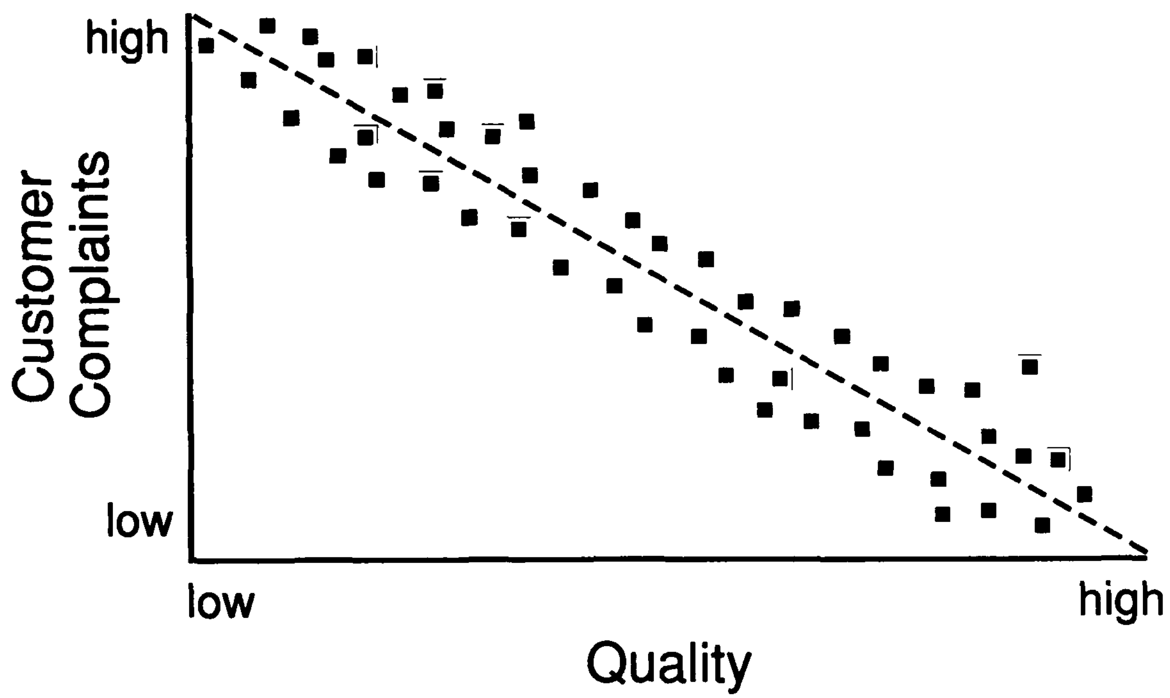
Positive Correlation



Variables change in the same direction.

How to Interpret a Scatter Diagram

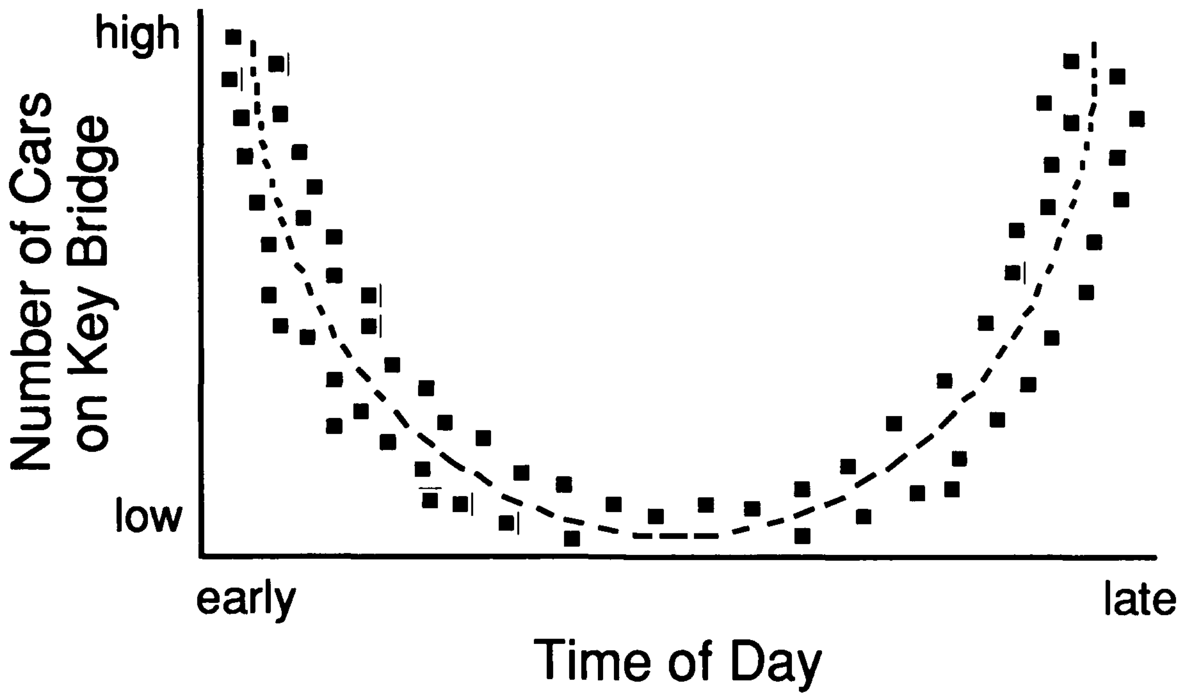
Negative Correlation



Variables change in the opposite direction.

How to Interpret a Scatter Diagram

Nonlinear Correlation



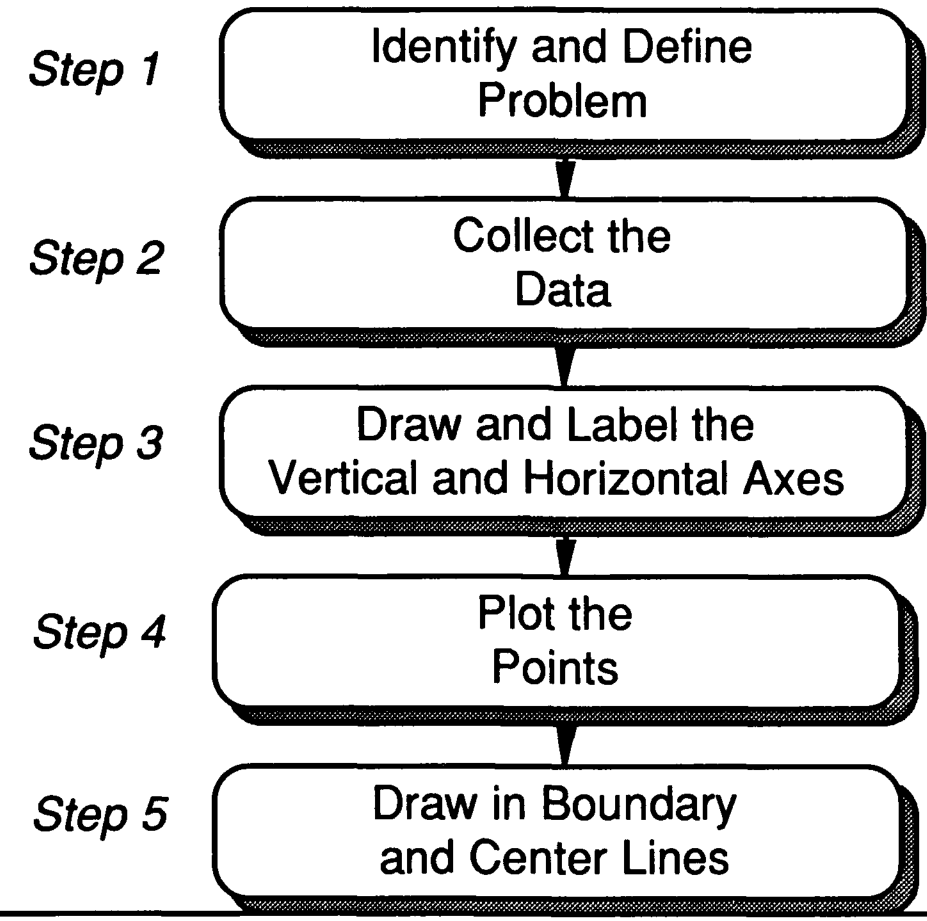
Variables follow a pattern that does not result in a straight "line of best fit."

How to Interpret a Scatter Diagram

No Correlation

Variables show no discernible pattern.

Constructing a Scatter Diagram



Constructing a Scatter Diagram

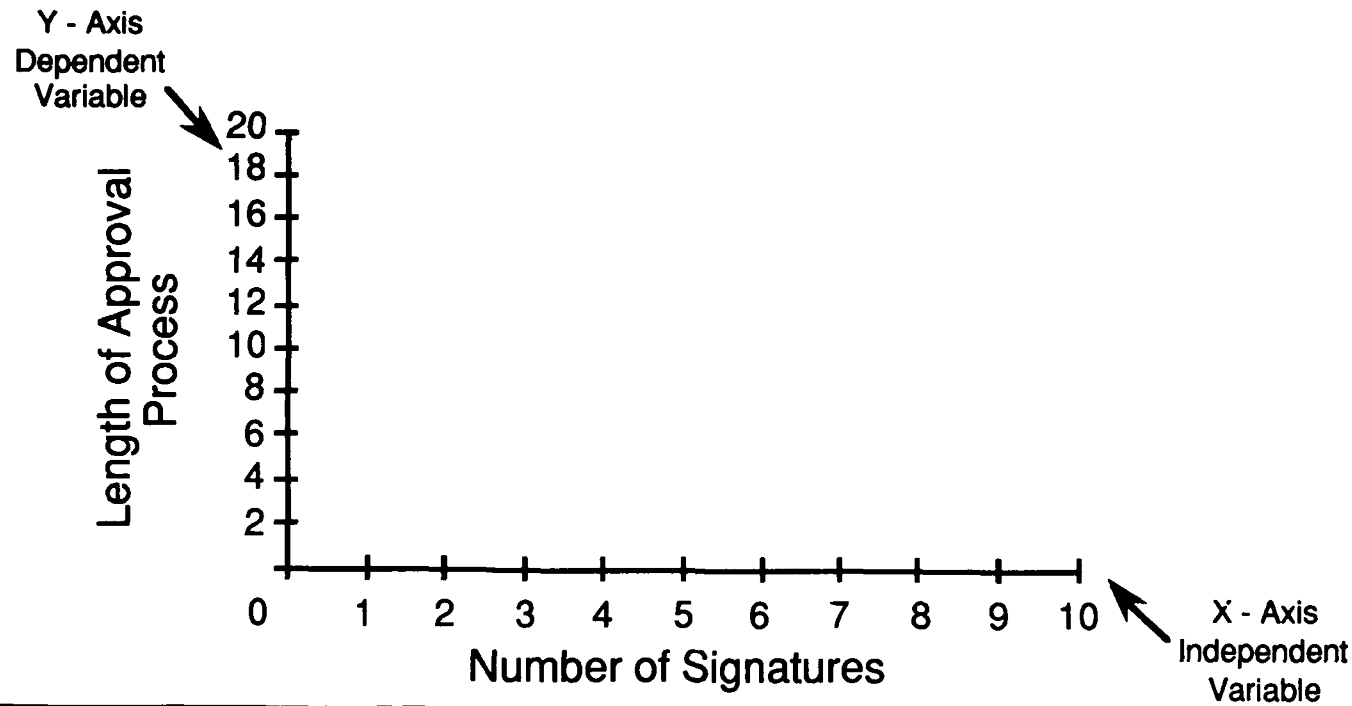
Step 2 Collect the Data

Sample	Variable X: Number of Signatures	Variable Y: Length of Approval Process
1	1	2 days
2	4	8 days
3	6	12 days
.		
.		
.		
50	3	6 days

Constructing a Scatter Diagram

Step 3

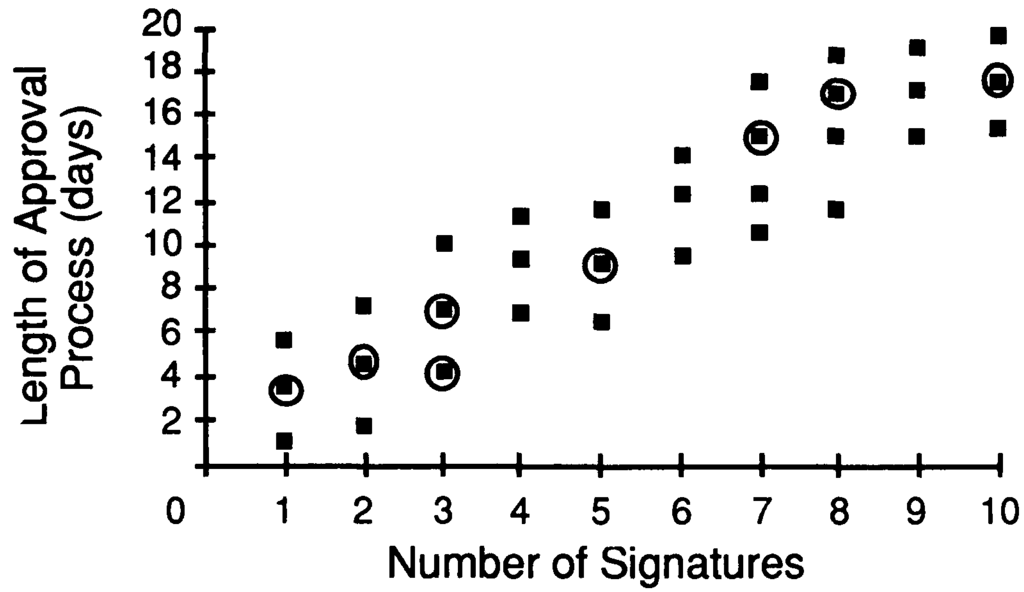
Draw and Label the Vertical and Horizontal Axes



Constructing a Scatter Diagram

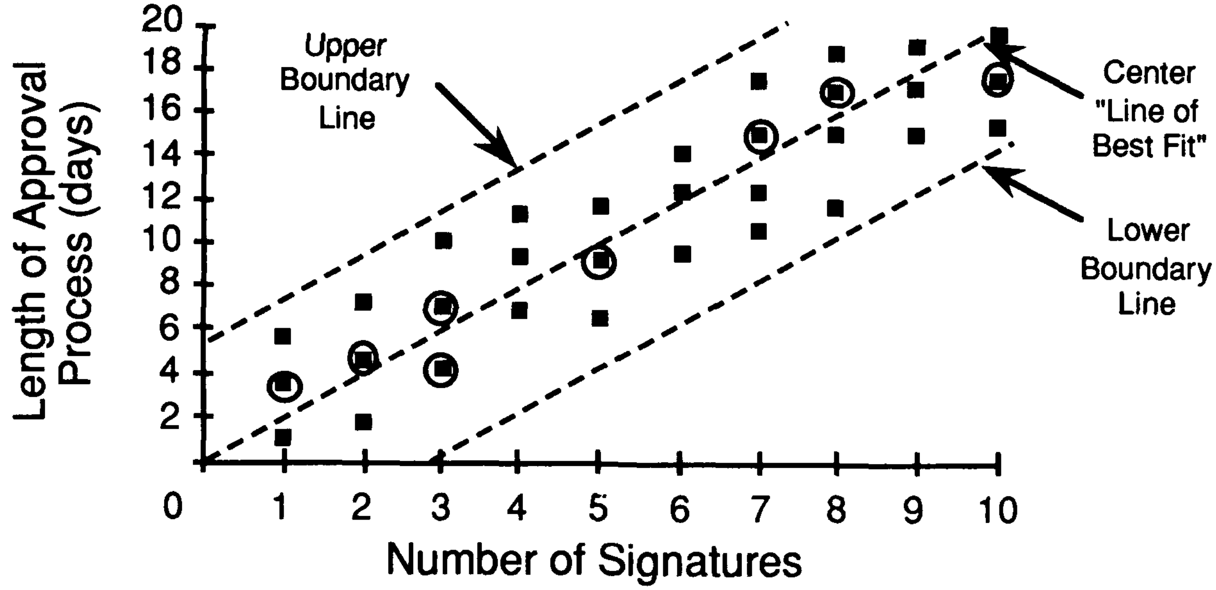
Step 4

Plot the Points



Constructing a Scatter Diagram

Step 5 Draw in Boundary and Center Lines



Scatter Diagram Construction/Interpretation Tips

CONSTRUCTION

- Data must be collected in pairs.

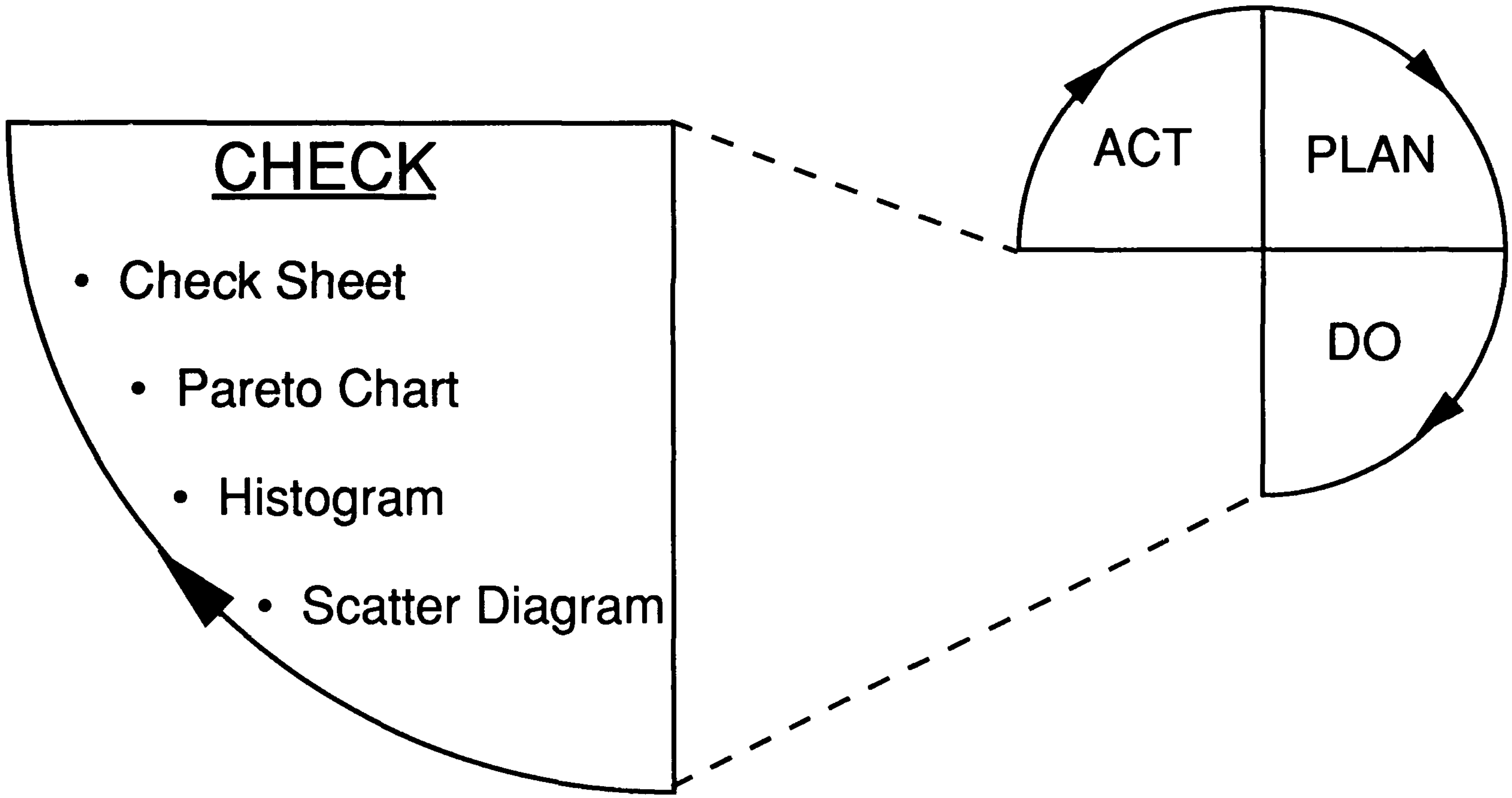
INTERPRETATION

- A scatter diagram can show a relationship or correlation between two variables, but it *cannot prove causation.*

Exercise 5-4

CONSTRUCTING A SCATTER DIAGRAM

The Use of Tools in the Check Step



Selection of Tools in the Check Step

Number of Variables	Type of Data	
	Qualitative	Quantitative
1	Pareto	Histogram
2	———	Scatter Diagram

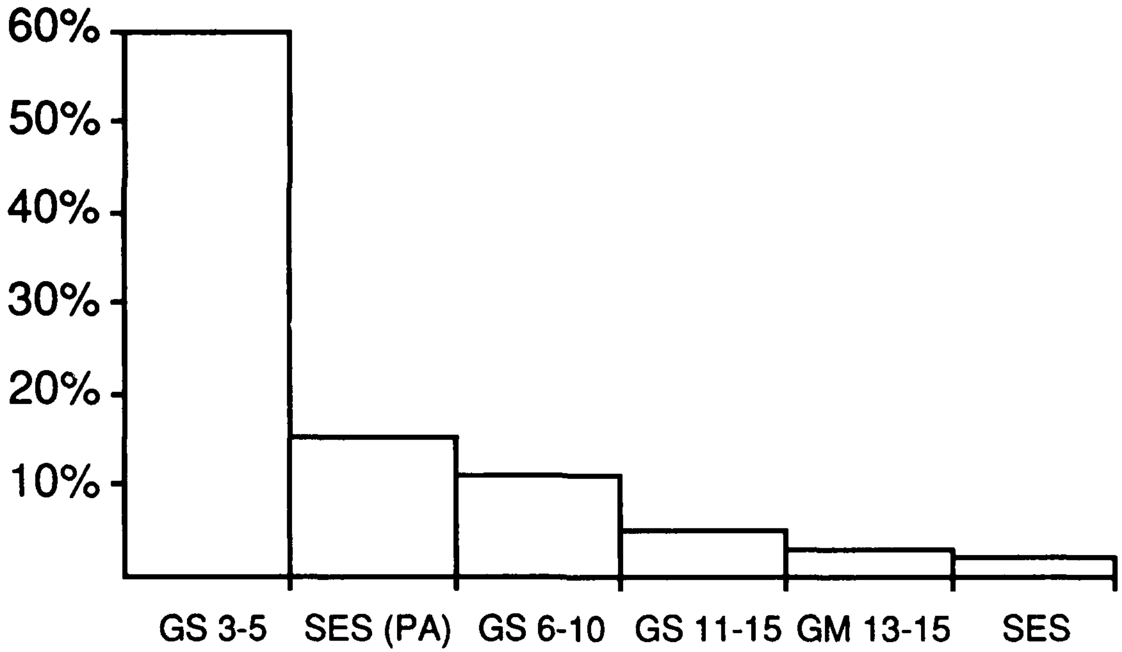
Selection of Tools -- Check Sheet

Personnel Turnover

	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	Total
GS 3 - 5	~~IIII~~	~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	60
GS 6 - 10	III	III	IIII	II	12
GS 11 - 15	I	II	I	I	5
GM13 - 15	I	I	0	I	3
SES	I	0	0	I	2
SES (PA)	III	IIII	~~IIII~~	III	15

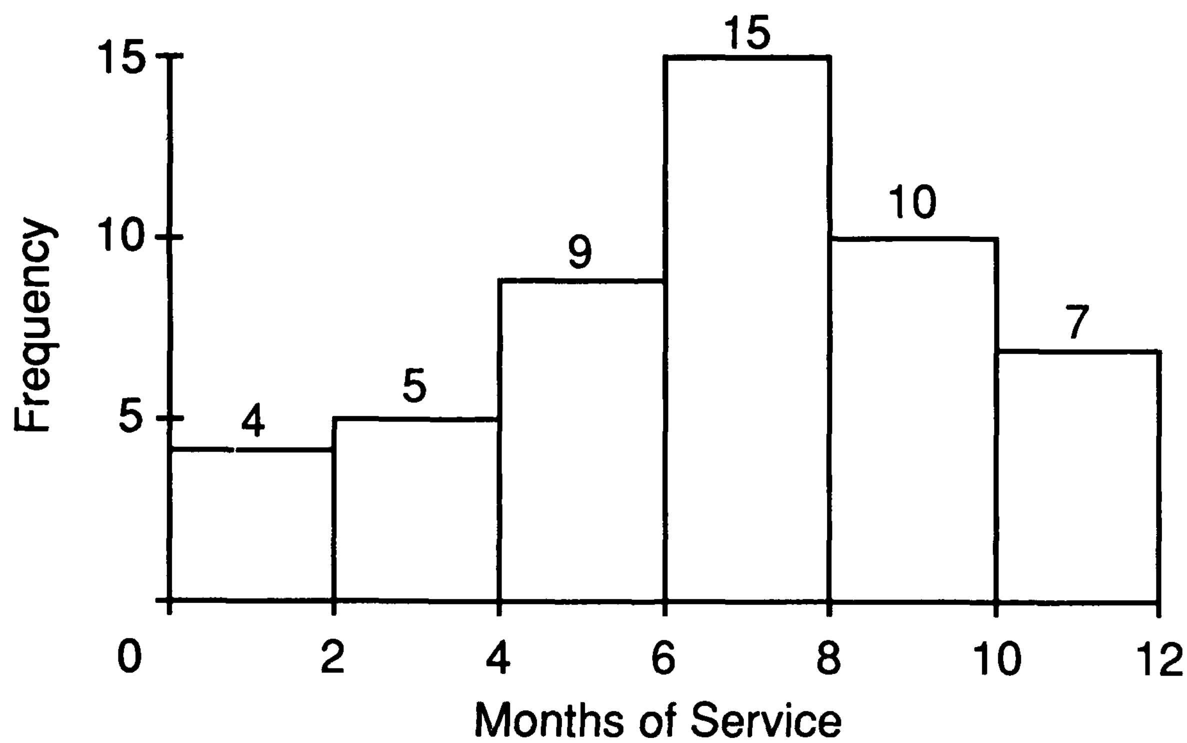
Selection of Tools -- Pareto Chart

Personnel Turnover



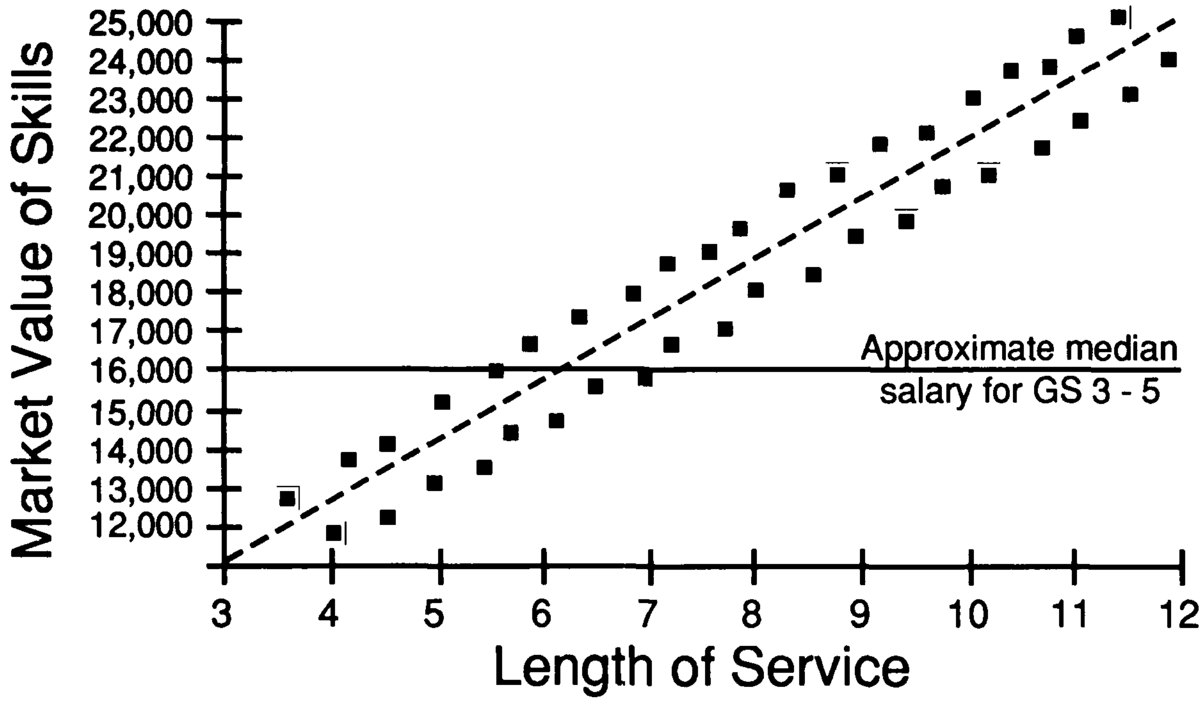
Selection of Tools -- Histogram

Personnel Turnover in GS 3 - 5 Positions



Selection of Tools – Scatter Diagram

Personnel Turnover in GS 3 - 5 Positions



MODULE SIX

CHECKING AND ACTING: CONTROL CHARTS AND RUN CHARTS

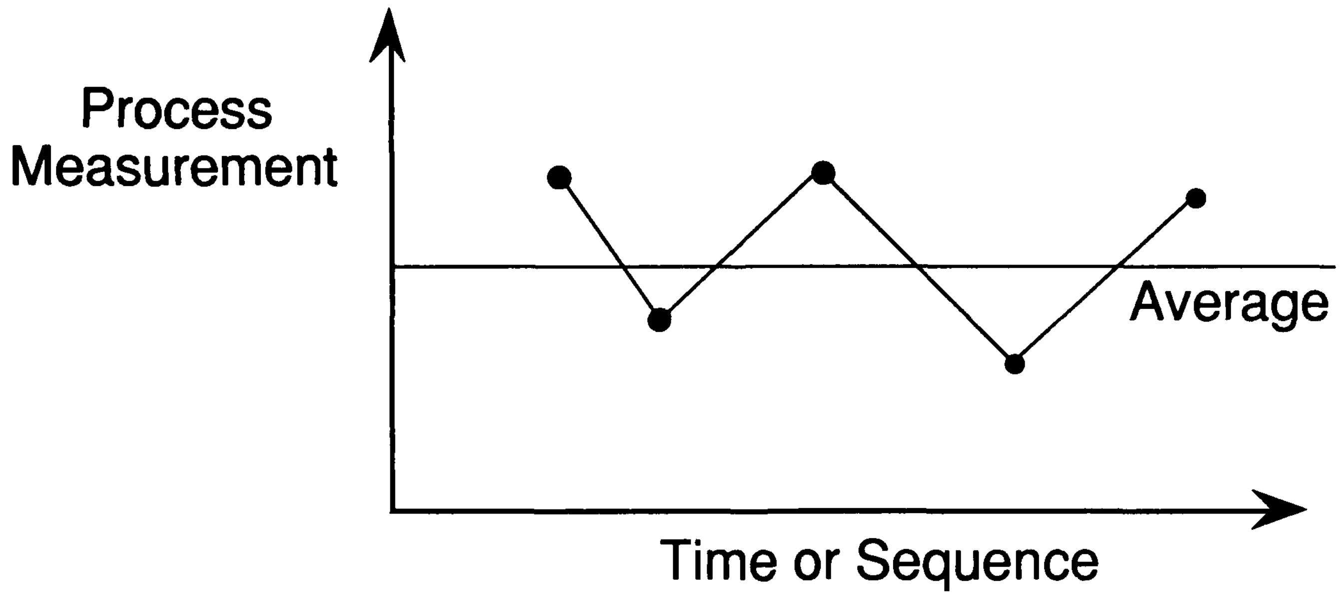
Module Six Objectives

Upon completion of this module, participants will be able to:

- Explain the design concept of the run chart.
- Construct and employ run chart methodology to record and interpret DoD process data.
- Explain the design concept of the control chart.
- Compare and contrast run charts and control charts.
- Calculate and determine control limits on control charts.
- Distinguish between special and common causes in a DoD process.
- Identify processes in a state of control versus an uncontrolled state.
- Explain courses of action for special causes and common causes of DoD process variation.
- Describe common management actions in response to process variation causes and why they are usually misguided.

What is a Run Chart?

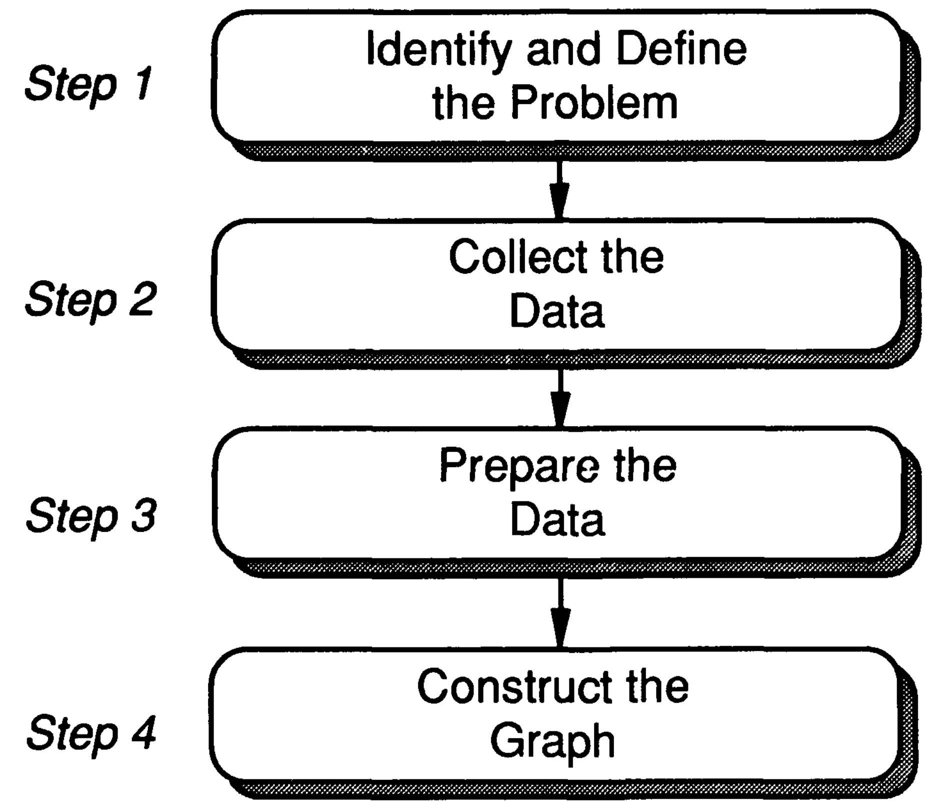
A run chart is a line graph that shows data plotted over time.



Why Use a Run Chart?

- Summarize
- Display Trends
- Monitor
- Before and After Analysis

Constructing Run Charts



Constructing Run Charts

Step 3 Prepare the Data

a. Determine the type of measure

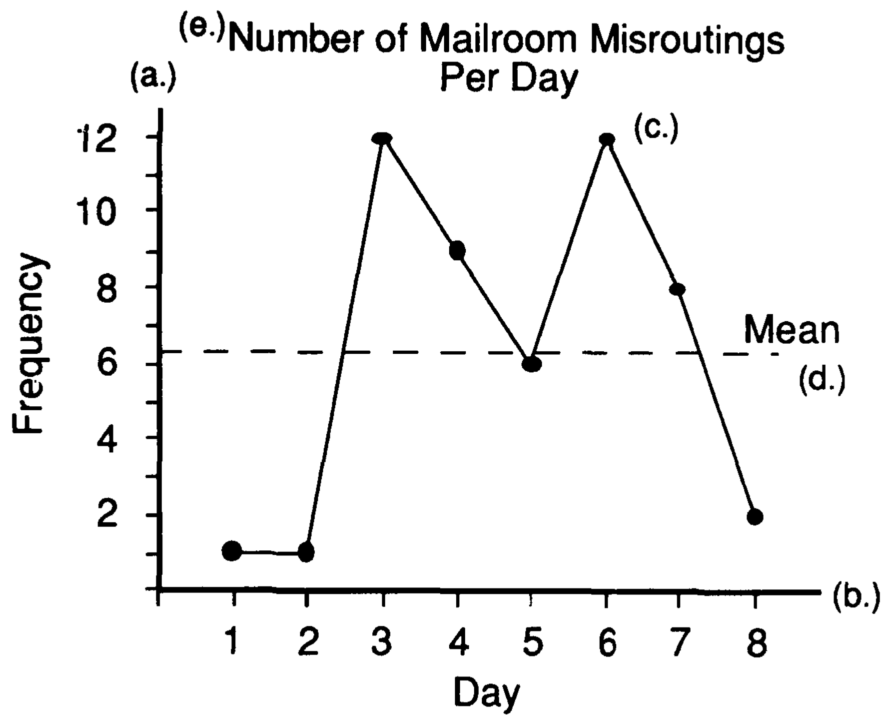
Day	***Frequency***	***Relative Frequency*** (Percentage)
1	1	2.0%
2	1	2.0%
3	12	23.5%
4	9	17.6%
5	6	11.8%
6	12	23.5%
7	8	15.7%
8	2	3.9%
Total	51	100%

b. Calculate the mean

51/8 = **6.38**	100%/8 = **12.5%**

Constructing a Run Chart

Step 4 Construct the Chart



a. Mark and label the vertical scale (measurements)

b. Mark and label the horizontal scale (time)

c. Plot the points and connect

d. Draw in the mean

e. Label the chart

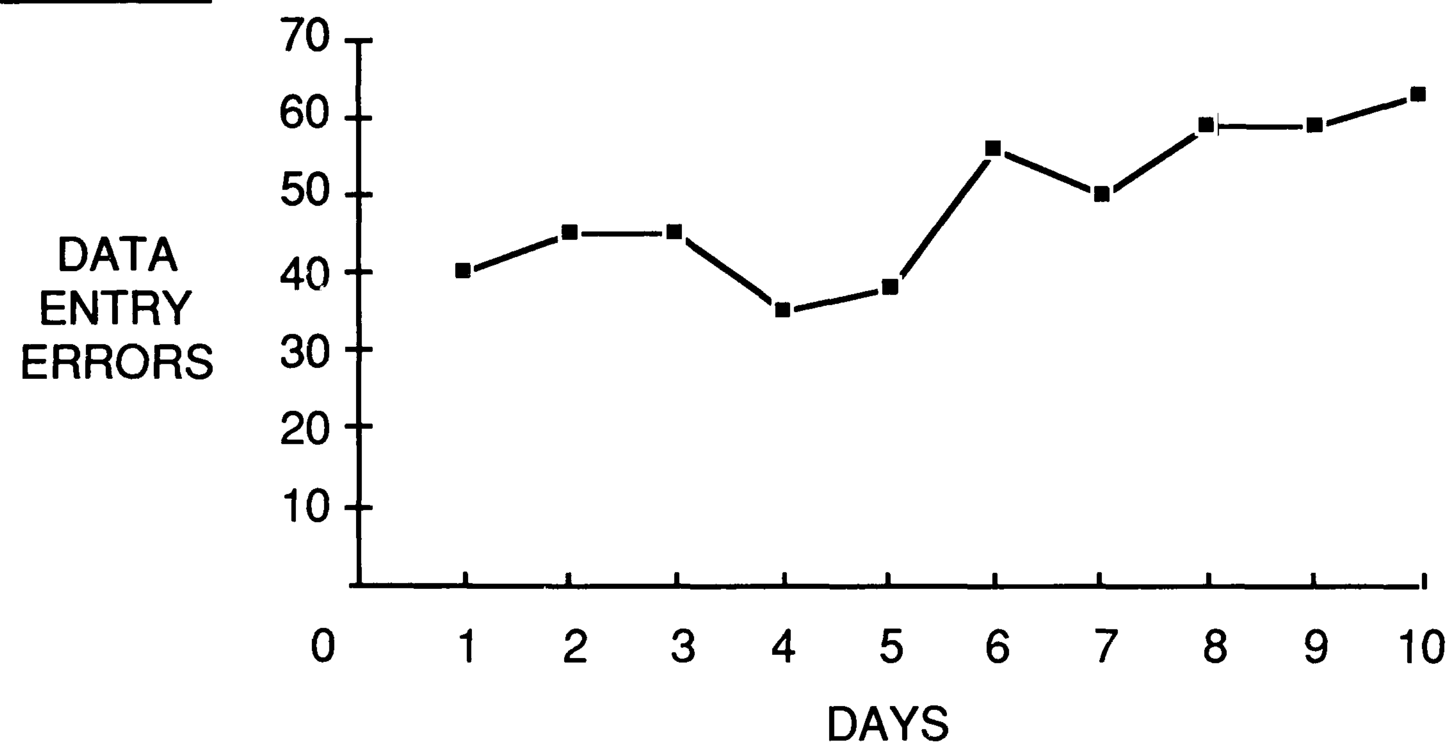
Interpreting Run Charts

RUN CHART PATTERNS

- Trend
- Shift in Level
- Cyclical Pattern
- Bunching
- Two Groups, Shift in Level
- Interaction Between Groups

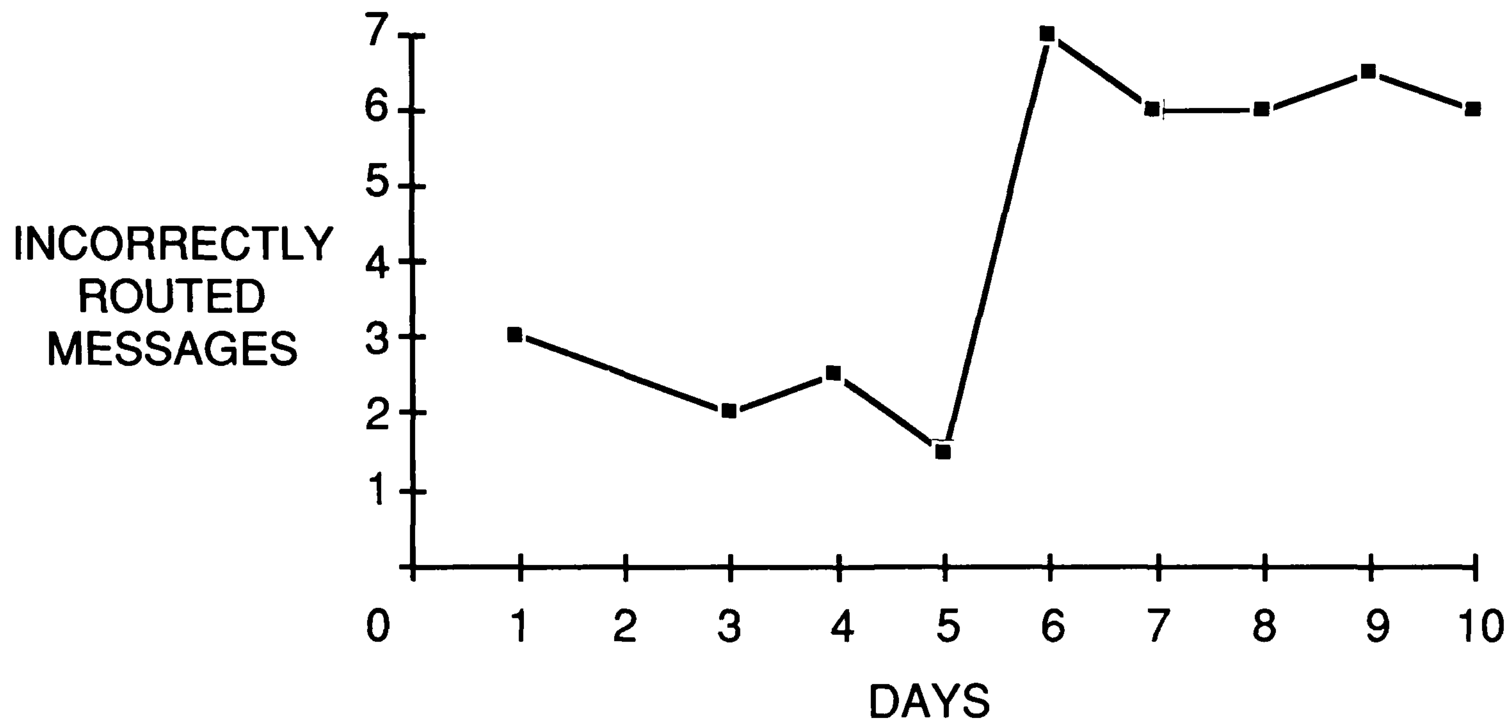
Interpreting Run Charts

TREND



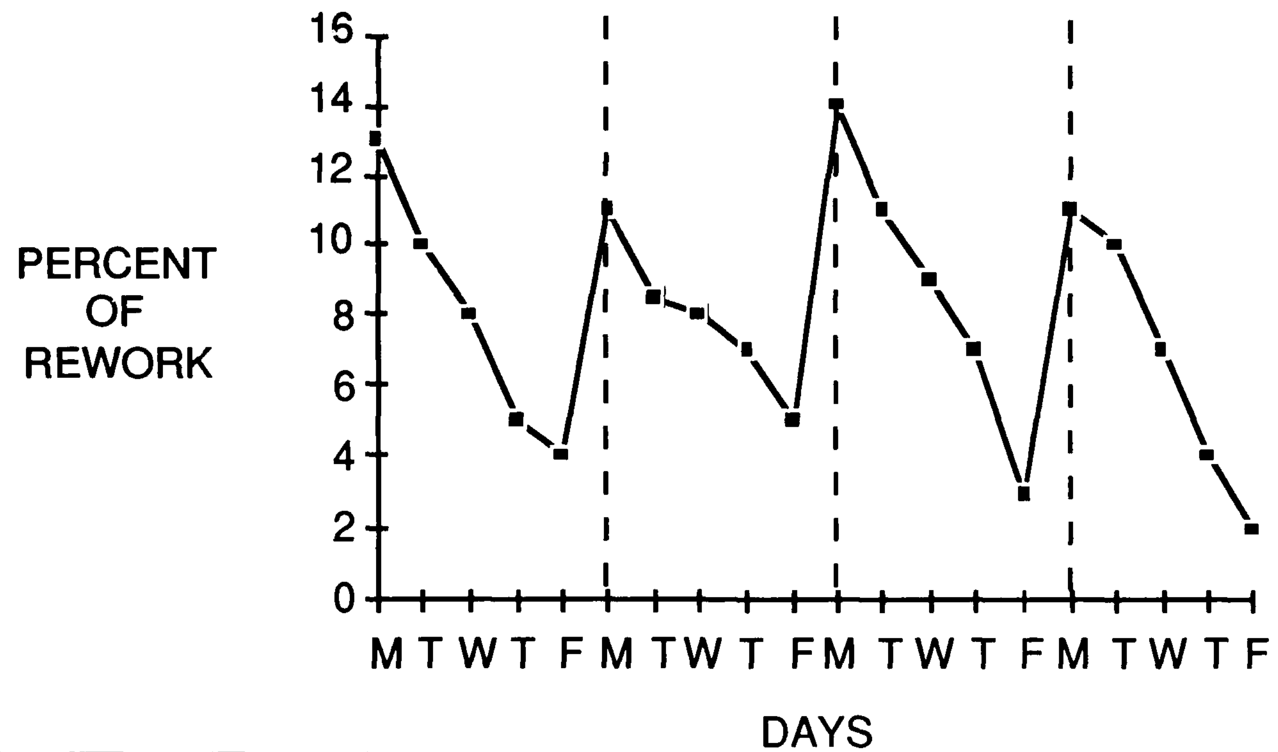
Interpreting Run Charts

SHIFT IN LEVEL



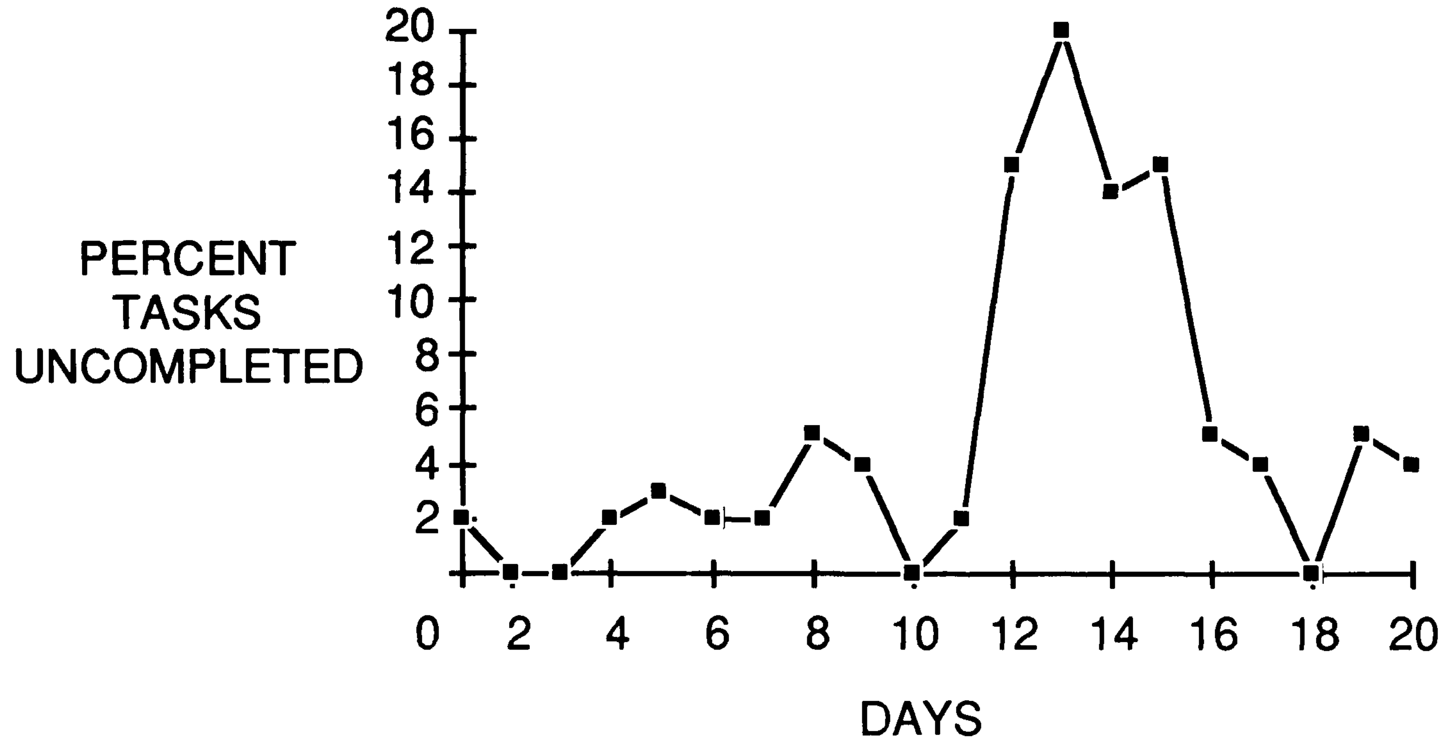
Interpreting Run Charts

CYCLICAL PATTERN



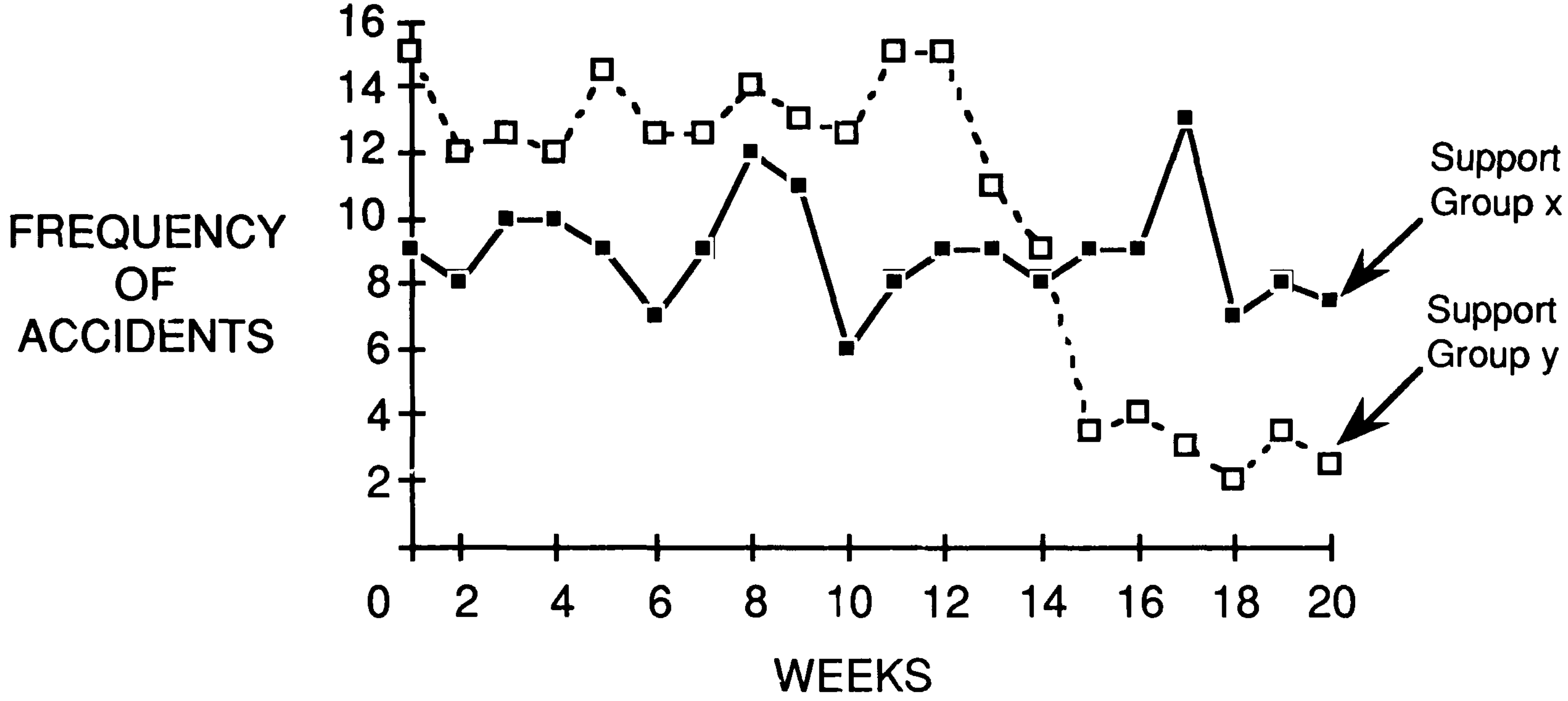
Interpreting Run Charts

BUNCHING



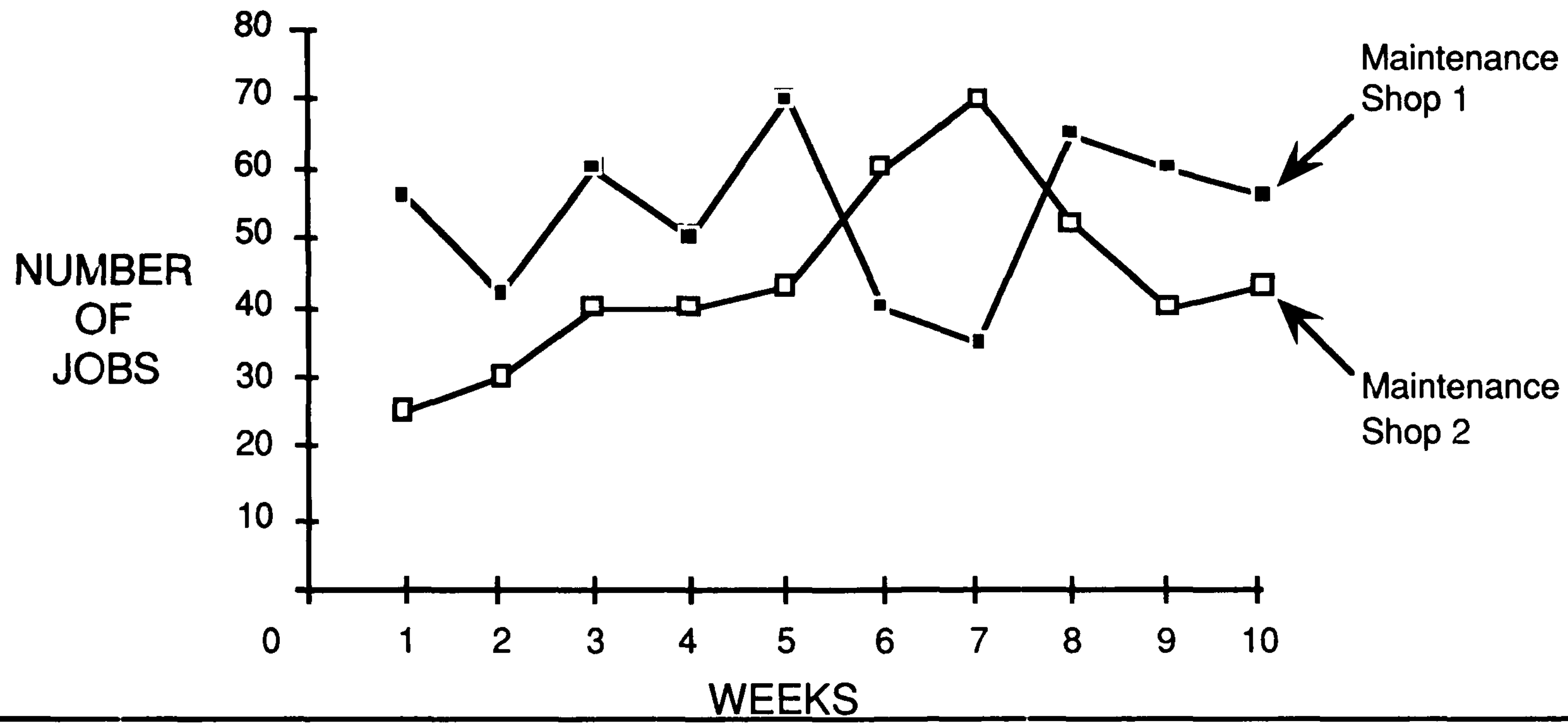
Interpreting Run Charts

TWO GROUPS, SHIFT IN LEVEL



Interpreting Run Charts

INTERACTION BETWEEN GROUPS



Exercise 6-1

BUILDING A RUN CHART

Final Tips and Reminders

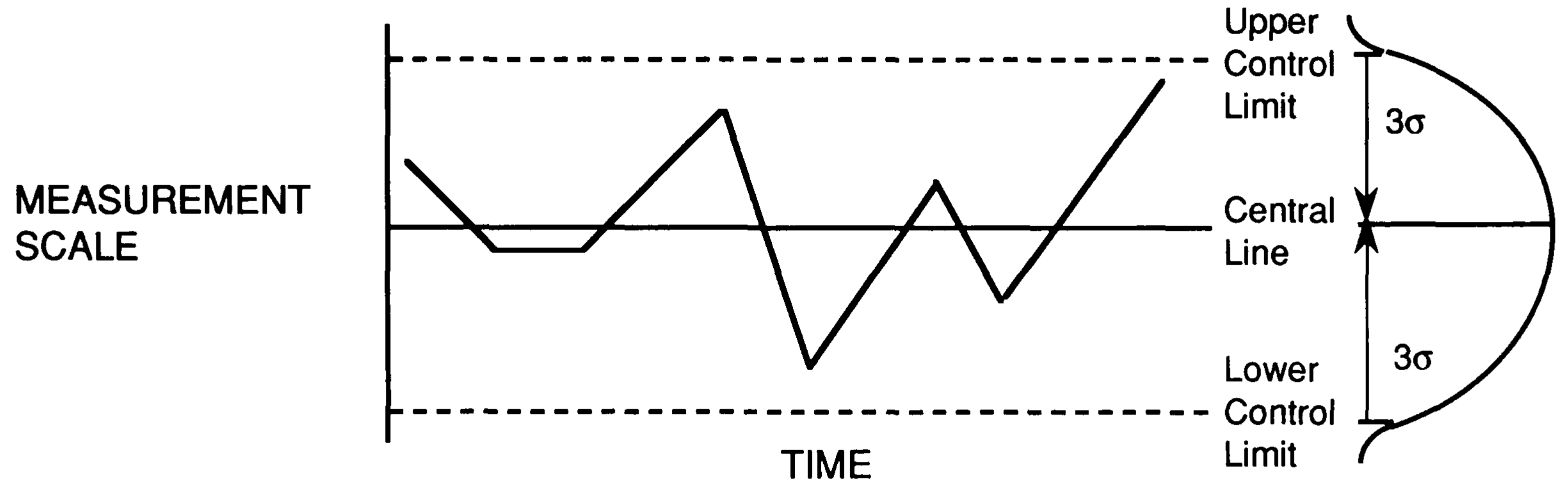
- There is a tendency to see every variation as important.
- Run charts should be used to *focus* attention on truly *vital changes.*

Checking and Acting: Control Charts and Run Charts

CONTROL CHARTS

What Is A Control Chart?

A Control Chart is a run chart with **statistically** determined upper (Upper Control Limit) and lower (Lower Control Limit) lines drawn on either side of the central line.



Why Use a Control Chart?

Judgment

- Determine if process in statistical control
- Distinguish special and common causes

Operation

- Achieve and maintain statistical control

Constructing a Control Chart

Step 1 Construct a Run Chart

↓

Step 2 Calculate and Plot the Control Limits

Exercise 6-2

CONSTRUCTING A CONTROL CHART

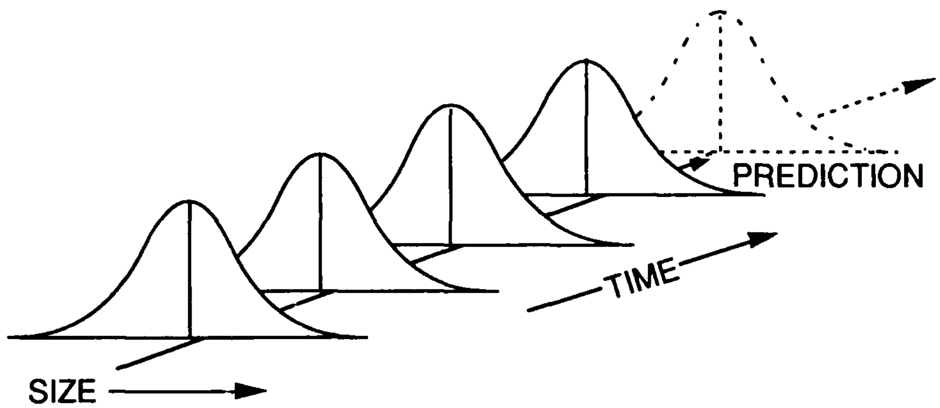
Process Control

- Variation: Common and Special Causes
- Process Control and Process Capability
- Process Control and Improvement Cycle
- Managerial Action

Variation: Common and Special Causes

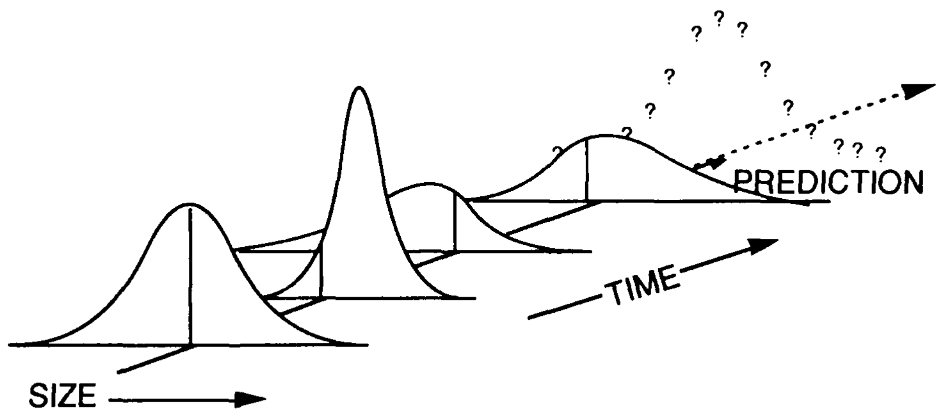
Common Causes:

Output of process forms a distribution that is stable over time and predictable.



Special Causes:

The process output is not stable over time and is not predictable.



Variation: Common and Special Causes

Special Cause → *Local Actions*

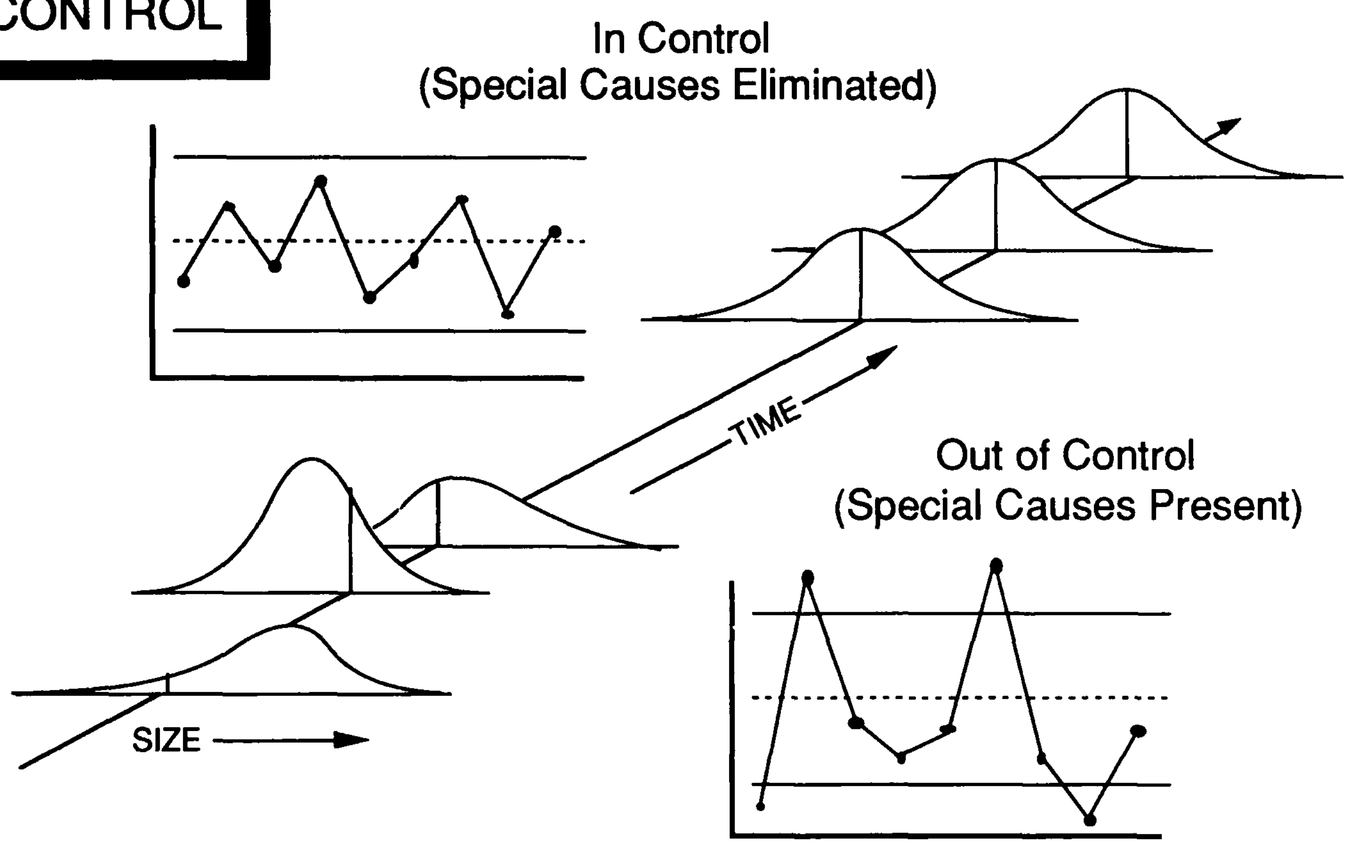
- Usually taken by people close to the process
- Can correct about 15% of process problems

Common Cause → *Actions on the System*

- Usually requires management action for correction
- Are needed to correct about 85% of process problems

Process Control and Capability

CONTROL

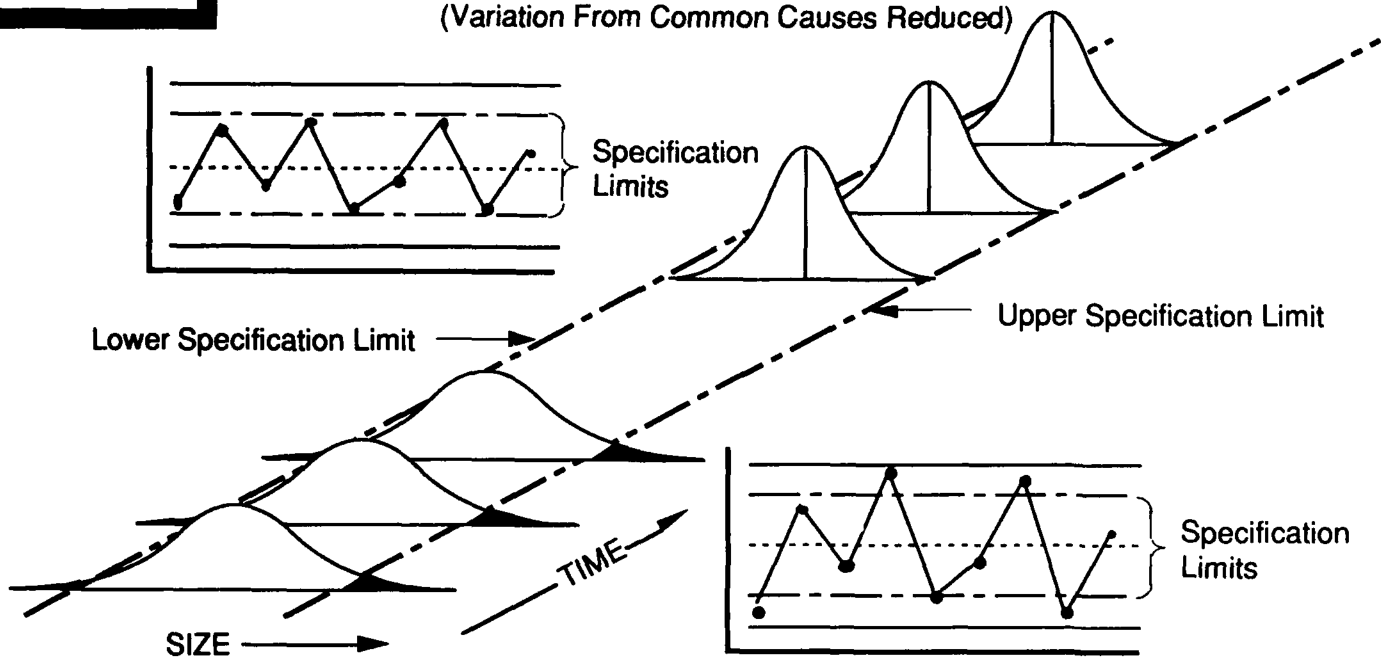


Process Control and Process Cability

CAPABILITY

In Control and Capable

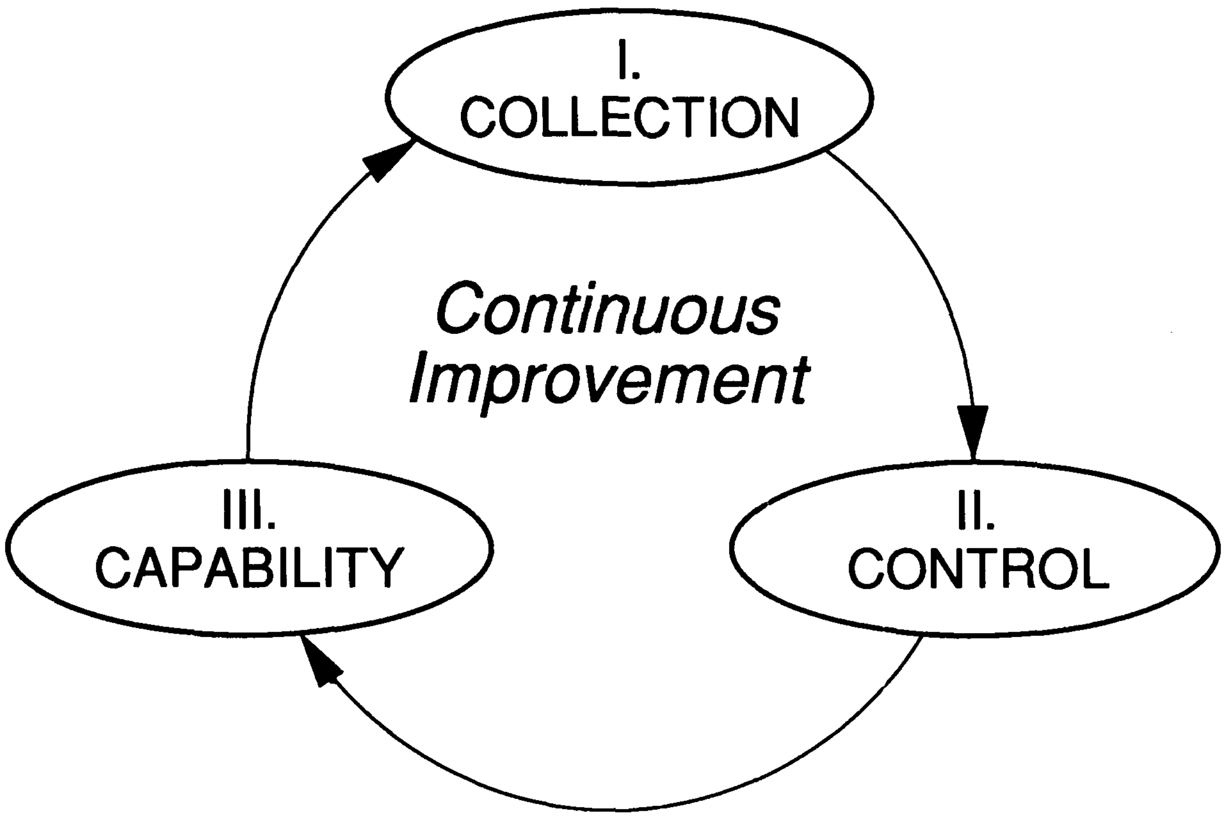
(Variation From Common Causes Reduced)



In Control but Not Capable

(Variation From Common Causes Excessive)

Process Control and Improvement Cycle



Process Control and Improvement Cycle

II. CONTROL

Step 1 — Construct A Control Chart

↓

Step 2 — Determine If Process In Control

↓

Step 3 — Eliminate Special Causes

↓

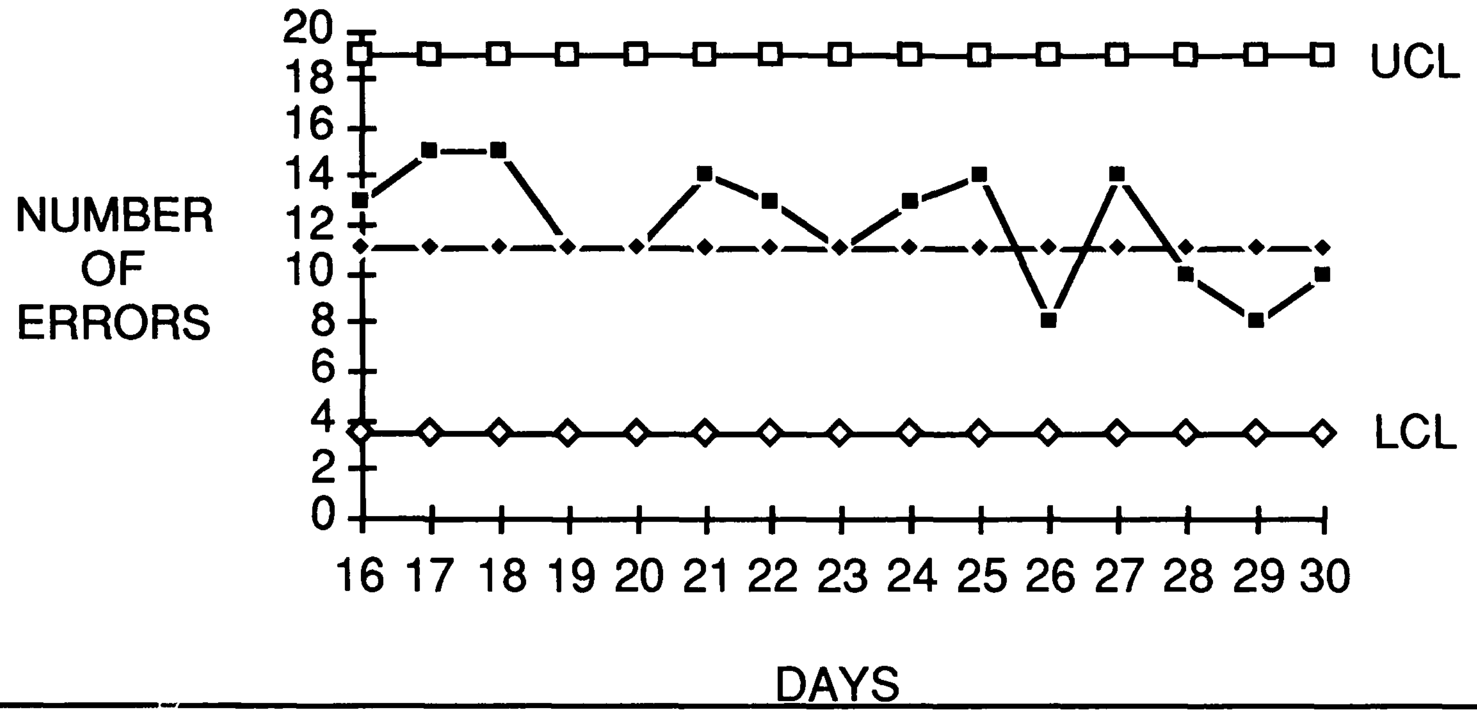
Step 4 — Recalculate Control Limits

Process Control and Improvement Cycle

II. CONTROL

Step 1

Construct A Control Chart



Process Control and Improvement Cycle

II. CONTROL

Step 2

Determine if
Process is In Control

IN CONTROL

- Most of the points are near the center line.
- A few of the points spread out and approach the control limits.
- None of the points exceed the control limits.
- There are no patterns (trends, cycles, etc.).

OUT OF CONTROL

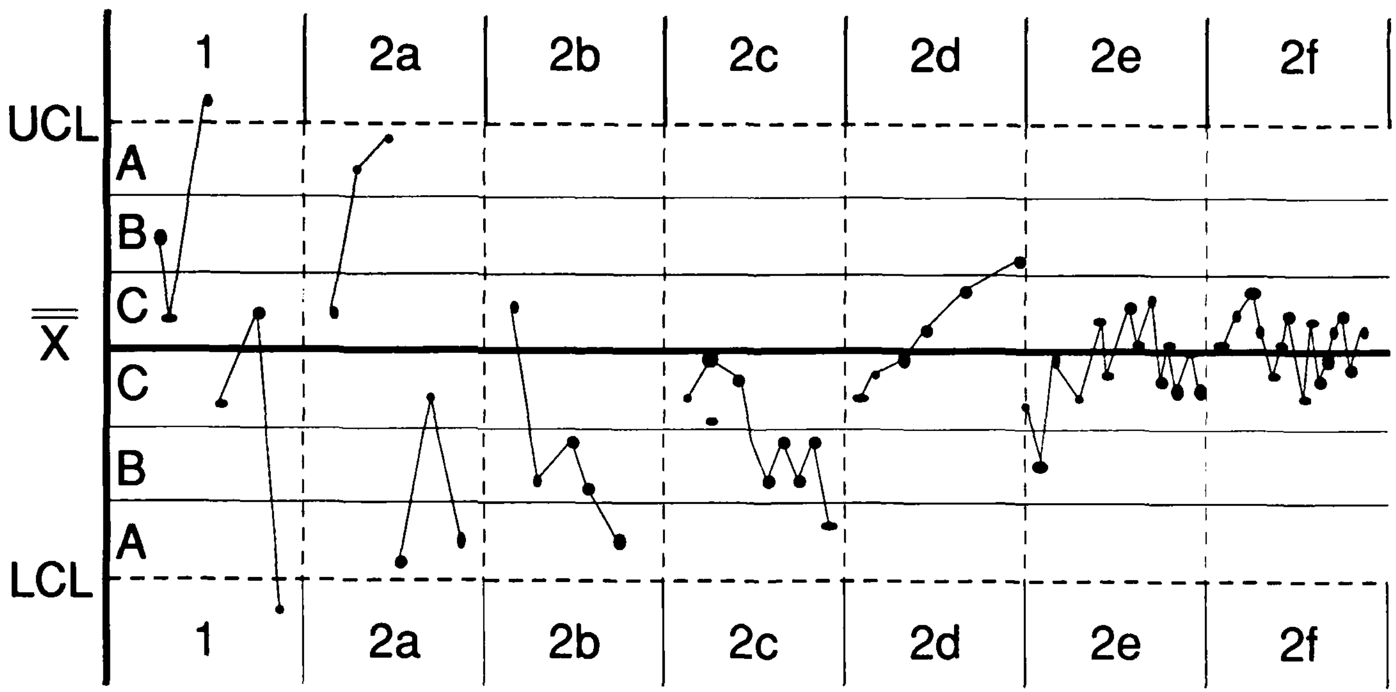
- Absence of points near the center line.
- Too many points near the control limits.
- Presence of points outside the control limits.
- Patterns are present.

Process Control and Improvement Cycle

II. CONTROL

Step 2

Determine if Process in Control



Process Control and Improvement Cycle

II. CONTROL

STEP 3 Eliminate Special Causes → *STEP 4* Recalculate Control Limits

STEP 3: Eliminate Special Causes

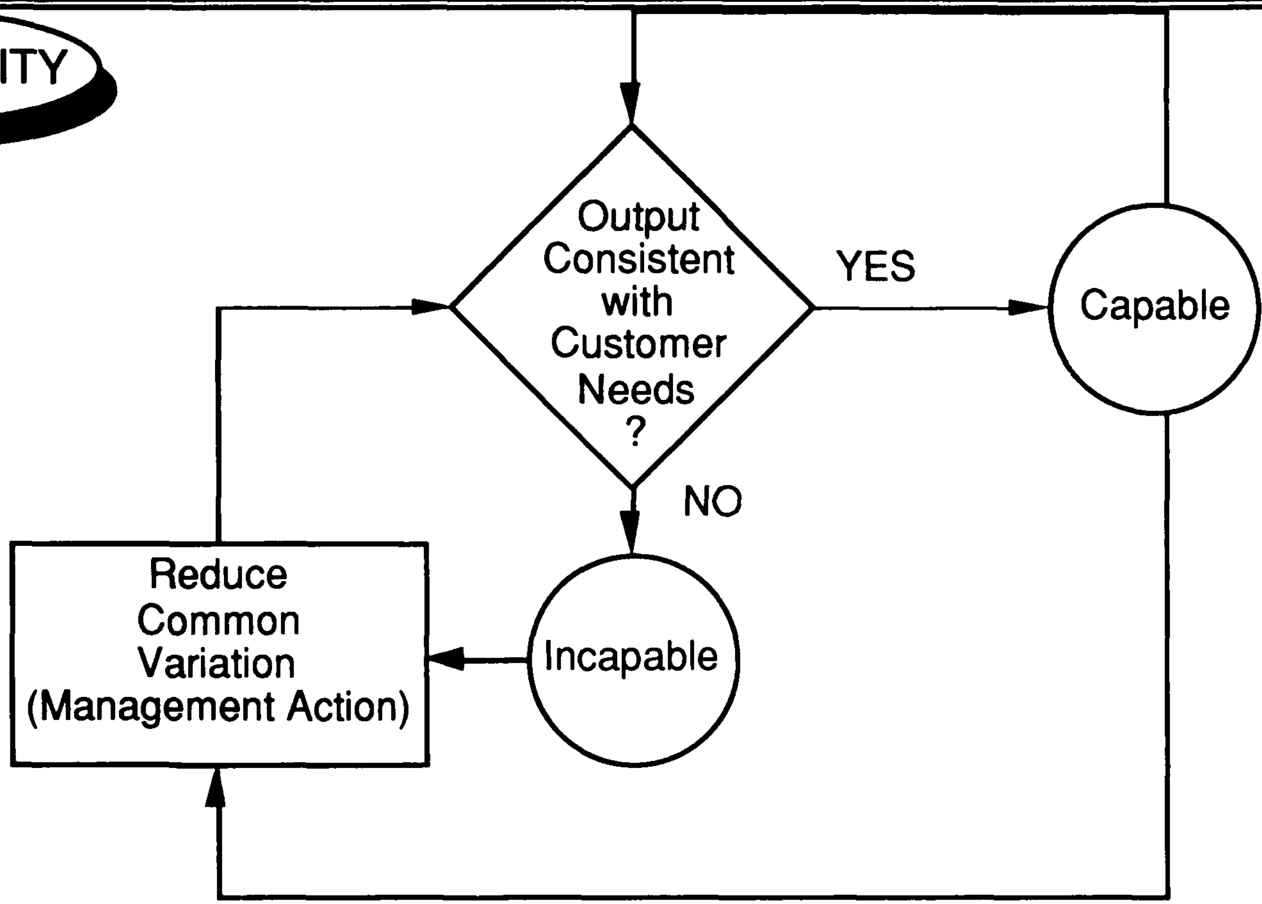
- Double check calculations for points in question.
- Determine source(s) of special cause(s).
- Eliminate special causes.

STEP 4: Recalculate Control Limits

- Throw out points outside control limits.
- Recalculate mean and control limits using entire data set.
- Chart data.

Process Control and Improvement Cycle

III. CAPABILITY



Exercise 6-3

CONSTRUCTING A CONTROL CHART TO DETERMINE PROCESS CONTROL

Managerial Action

Eliminating Special Causes of Variation

- Use timely data
- Isolate special causes as soon as possible
- Avoid unnecessary changes
- Try to prevent recurrence

Managerial Action

Eliminating Common Causes of Variation

- Communicate with personnel at all levels
- Keep measurement process manageable
- Use multiple analysis approaches
- Look for cause-and-effect relationships

Managerial Action

Some Common Mistakes

Overadjustment →
- Type I Error
- Deciding a cause is special when it is a common cause

Inaction →
- Type II Error
- Deciding a cause is common when the cause is special

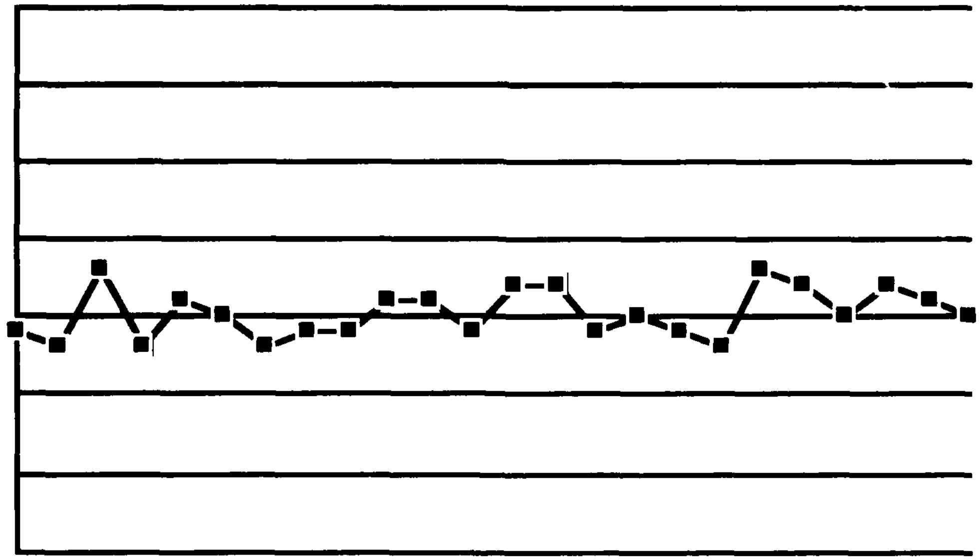
Tampering →
- Making changes to the process without a statistical reason
- Increases dispersion of a process

Exercise 6-4

THE QUINCUNX EXERCISE & THE IMPACT OF VARIATION

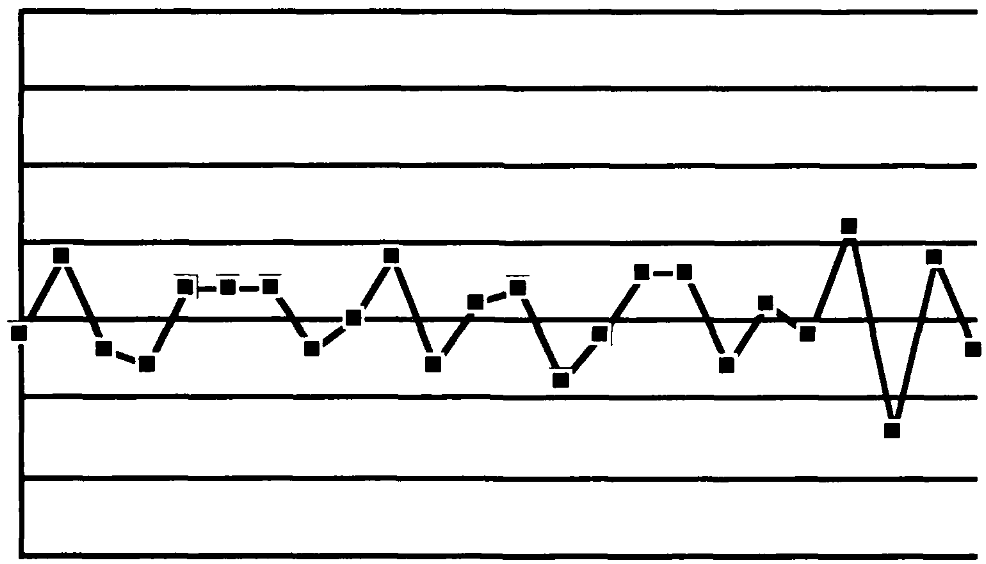
Exercise 6-4: The Quincunx Exercise

Rule 1
Sample Results



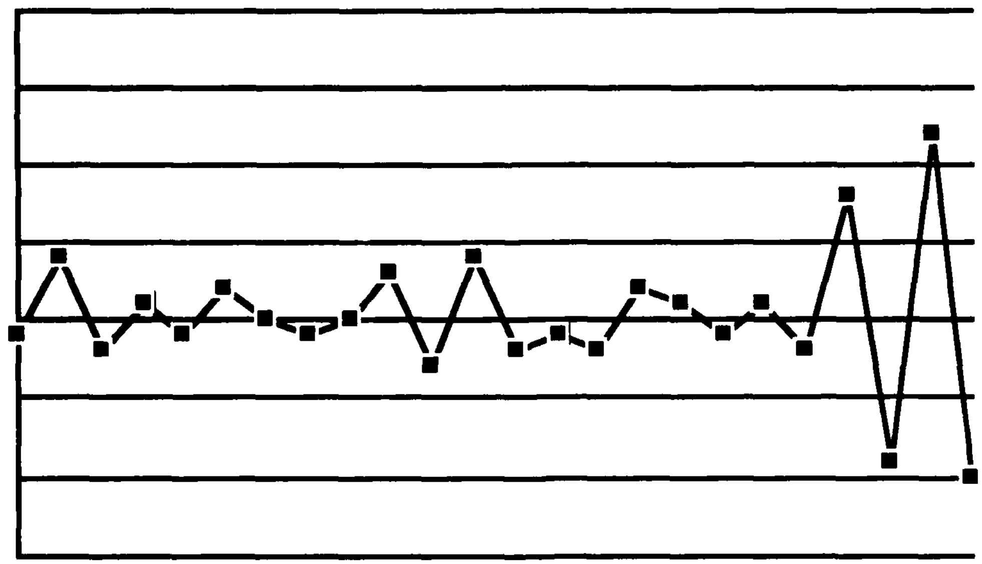
Exercise 6-4: The Quincunx Exercise

Rule 2
Sample Results



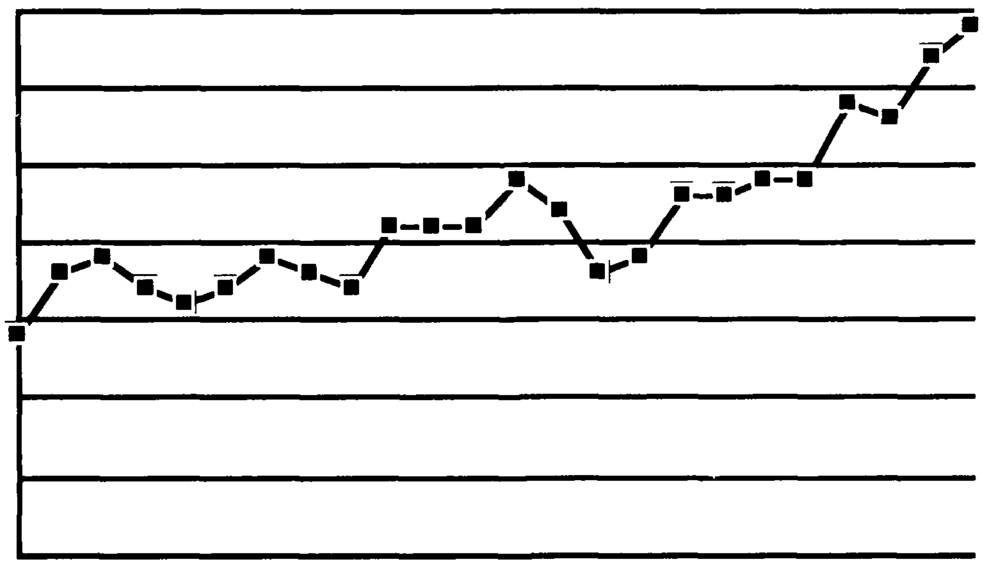
Exercise 6-4: The Quincunx Exercise

Rule 3
Sample Results



Exercise 6-4: The Quincunx Exercise

Rule 4
Sample Results



Exercise 6-4: The Quincunx Exercise

RESULTS FROM FUNNEL RULES

- Rule 1: Stable, miminal variance from target
- Rule 2: Stable, double the variance of rule 1
- Rule 3: Unstable, points wander in both directions
- Rule 4: Unstable, points wander in one direction

Exercise 6-4: The Quincunx Exercise

CONCLUSIONS

- Tweaking a stable process makes things worse
- Tweaking increases variation, risk and cost
- Adjusting a stable, well-targeted process is senseless tampering
- Statistical data will tell you when you should properly adjust a process